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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1895 *TO NOVEMBER* 1896.

VOL. LVI.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. NOVEMBER 8, 1895. No. 1

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

Antoine d'Abbadie, Membre de l'Institut des Sciences, Abbadia, Hendaye (Basses-Pyrenées), France;
Loyal H. Bradford, North Ferrisburgh, Vermont, U.S.A.;
Oswald Thomas Tuck, School Ship *Conway*, Birkenhead,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Hugh Lancelot Aldis, Secretary of Public Company, 67 Dieppe Street, West Kensington, W. (proposed by E. J. Spitta);
William Ernest Cooke, M.A., First Assistant Astronomer, Adelaide Observatory (proposed by Sir C. Todd);
Alpin G. Fowler, M. Inst. C.E., Civil Engineer, 1 Cambridge Road, Norbiton (proposed by W. H. M. Christie);
David Edward Hadden, Alta, Buena Vista Co., Iowa, U.S.A. (proposed by L. A. Eddie);
The Rev. Robert Killip, Sale, Manchester (proposed by Sir R. S. Ball);
George Handley Knibbs, Lecturer in Surveying, University, Sydney, New South Wales, Australia (proposed by R. T. A. Innes);
Frederick William McCarthy, Practical Astronomer, 20 Chepstow Place, Bayswater, W. (proposed by J. McCarthy);
Charles J. Merfield, Department of Public Works, Sydney, New South Wales, Australia (proposed by R. T. A. Innes);
Hugh Griffith Quirk, Master Mariner, Baymount, Vico Road, Dalkey, co. Dublin (proposed by S. M. Yeates).

One hundred and ninety-five presents were announced as having been received since the last meeting, including, amongst others :—

American Nautical Almanac Papers (Newcomb, Tables of the Sun and *Mercury*; Hill, Tables of *Jupiter* and *Saturn*), presented by the American Nautical Almanac Office; Aratus, Astronomy and Meteorology, translation of, presented by C. L. Prince; Sir R. S. Ball, Great Astronomers, presented by the publishers; J. Bossert, Catalogue des mouvements propres d'étoiles, presented by the author; Cape Catalogue of 1,713 Stars, presented by the Observatory; A. Cayley, Collected Mathematical Papers, vol. viii., presented by the author; Cincinnati Observatory Publications, No. 13 (Porter, catalogue of 2,000 stars), presented by the Observatory; A. M. Clerke, The Herschels and Modern Astronomy, presented by the author; Greenwich Observations, &c., 1892, presented by the Royal Observatory; Nice Observatoire, Annales, tomes iv., v., presented by M. Bischoffsheim; J. A. C. Oudemans, Triangulation von Java, presented by Professor Oudemans; W. F. Stanley, Notes on the Nebular Theory, presented by the author; Photograph of part of Milky Way, presented by Dr. Sheldon; Photographs of Hammerfest and Vadsö, presented by T. R. Clapham.

Reproduction of Astronomical Photographs.

In continuation of the note in the June number of the *Monthly Notices*, a further list of photographs now on sale to Fellows is given below.

Lantern slides can now also be obtained of any of these, and of those included in the former list.

Price of prints, 1*s.* 6*d.* each; slides, 1*s.* each. In ordering prints please state whether platinotype or aristotype are required. The R.A.S. reference number need only be quoted: orders to be addressed to W. H. Wesley.

R.A.S. Reference No.	Subject.	Photograph by
13	Comet *c* 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet *c* 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet *c* 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet *a* 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet *f* 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet *a* 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	MM. Lœwy and Puiseux

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Note on the Value of the Longitude in the Lunar Theory when the Sun's Mass is put Zero. By P. H. Cowell, B.A., Fellow of Trinity College, and Isaac Newton, Student in the University of Cambridge.

(*Communicated by F. W. Dyson, M.A.*)

About fifteen years ago a paper was published in Silliman's journal * by Mr. Stockwell, in which he called attention to the fact that when the mass of the Sun, and therefore its mean motion, is put equal to zero, Delaunay's expression for the longitude † does not degenerate into the ordinary formula for elliptic motion, but contains terms in which the Sun's eccentricity, and the position of the Sun's apse, and the ratio of the parallaxes enter. Mr. Stockwell argued that there must therefore be "something seriously wrong" with Delaunay's analysis.

Mr. Stockwell's objection has been discussed by M. Gogou.‡ He has shown that when the Sun's mass is zero, and consequently when the Moon's node and apse are fixed, certain operations of Delaunay's may be modified. Some terms with different arguments coalesce, and the accuracy of Delaunay's results is fully established, so far as the terms objected to by Mr. Stockwell are concerned.

M. Gogou's work, which involves a modification of several of Delaunay's operations, is very long and laborious. Moreover it merely verifies Delaunay's terms without explaining the physical (in contradistinction to the analytical) reason why such terms should exist. In this paper the question is treated from a different standpoint; the mean motion of the Sun, instead of being put zero, is made to diminish without limit.

At the beginning of his analysis Delaunay replaced the mass of the Sun m' by $n'^2a'^3$ (his notation is well known, and it is unnecessary to explain the meaning of the symbols that occur in this paper); whereas, more accurately, the relation is

$$\mu + m' = n'^2a'^3,$$

μ being the mass of the Earth. Delaunay's analysis is therefore founded upon the assumption that the Sun's mass is extremely large in comparison with the Earth's. Now, when we suppose n' to be diminished to a very small fraction of its actual value, we must either suppose a' increased or m' diminished. It is inconvenient to suppose a' increased, as it would diminish some of the terms in Delaunay's degenerate expression that we are about to consider, and an explanation of them as they stand is more

* *American Journal*, vol. xx. 3rd series, 1880.

† *Mémoires de l'Académie des Sciences*, vol. xxix. ch. xi.

‡ *Annales de l'Observatoire de Paris*, vol. xviii. 1885.

satisfactory. On the other hand, if m' is greatly diminished, the Earth's mass may not be neglected in comparison with it. Now Delaunay's final expression for the longitude has been calculated to the seventh order of small quantities. The quantities neglected, being of the eighth order, are comparable with 10^{-8} or 10^{-9}, whereas the ratio $\mu : m'$ is apparently 3×10^{-6}. Again, if E be the mass of the Earth, M the mass of the Moon, Delaunay neglects M/E. We know, however, that if we replace $1/a'$ by $(E-M)/(E+M)a'$ wherever it occurs in Delaunay's final expression, the parallactic terms that contain the first power of the ratio of the parallaxes are by this change rendered perfectly accurate, but the terms containing the square and higher powers of the ratio of the parallaxes are not rendered accurate in this manner, though the error is very small, and probably is comparable with 10^{-7}. A physical interpretation must be given to the simplifications (such as neglecting μ/m') introduced by Delaunay, and then his results become the solution, accurate to the seventh order, of a definite problem, different—but not very different—from the problem actually presented by the Moon.

We are led, therefore, to examine what physical problem Delaunay has actually solved.

In the problem of two bodies, the Earth and Sun, suppose we have the relation

$$\mu + m' = n'^2 a'^3.$$

If, however, one of the two bodies be supposed fixed (in the same sense that the centre of gravity of two or more free bodies may be supposed fixed), we may conceive that one body attracts the other, but is not attracted by it, or else that external forces are called into play, neutralising the attraction of the second body upon the first; the relation then becomes

$$m' = n'^2 a'^3,$$

which is that used by Delaunay. Delaunay, therefore, solves the following problem—to investigate the motion, supposed nearly circular, of a Moon of no mass under the attraction of the Earth and disturbed by a distant Sun, which produces acceleration in both the Earth and Moon according to Newton's law, but which is not itself affected by attractions from them.

This is a definite problem, and one that reduces to elliptic motion when the Sun's mass vanishes. Moreover, when the Sun's mass is large the error in supposing the Sun at rest instead of the centre of gravity at rest is not large, although larger than some of the terms given by Delaunay. When the Sun's mass is small the problem ceases to have any resemblance to that of three free bodies.

Let us suppose the Sun's mass so small that n'/n is of the seventh order of small quantities. Then no periodic term in the

solution due to the action of the Sun is of a lower order than the eighth, and the motion must therefore be sensibly elliptic. However, the node and apse move continually in one direction, although with extreme slowness, so that after the lapse of a long time the ellipse described is a distinctly different one. Analysis also shows that the eccentricity and inclination undergo finite variations (that is to say, variations that do not become insensible when m is insensible). The eccentricity and inclination at any instant turn out to be functions of the configuration of the node and apses, and are therefore only constant when the configuration remains unchanged, that is to say, when m' and n' are absolutely zero.

The explanation of the terms discussed by Mr. Stockwell and M. Gogou, therefore, is that, when terms containing m are neglected, Delaunay's expressions must represent, not merely elliptic motion in one definite and fixed ellipse, but must be capable of representing motion in any one of that doubly infinite variety of ellipses, with which the sensible motion coincides, when any arbitrary values are given to the longitudes of apse and node.

It remains to verify the foregoing explanation by showing that by formulæ of transformation that involve the configuration of node and apses only Delaunay's degenerate expressions can be identified with the expressions for elliptic motion. Assuming, therefore, the identity of Delaunay's degenerate expression for the longitude with the expression in purely elliptic motion for all values of the time, we may separately equate those terms whose speed is the same multiple of the mean motion. We shall therefore obtain the relations we seek from the terms in the longitude whose speed is the mean motion or twice the mean motion, and we shall verify the algebraic work by a comparison of those terms whose speed is three times the mean motion. This verification will also constitute a sufficient guarantee of the accuracy of the foregoing explanation as to the reasons why the terms under discussion appear. It appears scarcely necessary to perform the corresponding algebraic work for the terms in the latitude and parallax and the terms of shorter period in the longitude.

We give below those terms in Delaunay's expression for the longitude that are independent of m, and whose speed is once, twice, or thrice the mean motion. We restore Delaunay's notation of l, g, h, g', h' (in chapter xi. he has used the symbols D, F, l), and we write χ for $h+g-h'-g'$, the distance between the apses, and we notice that there are no terms containing l'. This last fact is a confirmation of the theory, because there are no terms of corresponding speed in the purely elliptic expression. The expression referred to is

$$\left(2e-\frac{1}{4}e^3+\frac{5}{96}e^5\right)\sin l$$

$$+\left(-3\gamma^2e-18\gamma^4e+\frac{61}{8}\gamma^2e^3-\frac{447}{4}\gamma^6e+92\gamma^4e^3-\frac{925}{96}\gamma^2e^5-\frac{165}{16}\gamma^2e\frac{a^2}{a'^2}\right)\sin(2g+l)$$

$$+\left(\frac{7}{6}\gamma^2e^3+\frac{359}{12}\gamma^4e^3-\frac{285}{64}\gamma^2e^5\right)\sin(2g-l)$$

$$+\frac{11}{24}\gamma^4e^3\sin(4g+l)$$

$$+\frac{165}{64}ee'^2\frac{a^2}{a'^2}\sin(2\chi+l)$$

$$+\left(\frac{5}{2}e'-\frac{15}{2}\gamma^2e'+\frac{15}{2}e^2e'+\frac{5}{2}e'^3+\frac{15}{2}\gamma^4e'-\frac{55}{2}\gamma^2e^2e'+\frac{465}{128}e^4e'\right)\frac{a}{a'}\sin(\chi+l)$$

$$+\left(\frac{105}{16}e^2e'-\frac{365}{16}\gamma^2e^2e'+\frac{385}{96}e^4e'\right)\frac{a}{a'}\sin(\chi-l)$$

$$+\frac{205}{16}\gamma^2e^2e'\frac{a}{a'}\sin(\chi+2g+l)$$

$$+\left(\frac{5}{6}\gamma^2e'+\frac{5}{3}\gamma^4e'+\frac{145}{48}\gamma^2e^2e'\right)\frac{a}{a'}\sin(\chi-2g-l)-\frac{115}{144}\gamma^2e^2e'\frac{a}{a'}\sin(\chi-2g+l)$$

$$+\left(\frac{5}{4}e^2-\frac{5}{4}\gamma^2e^2-\frac{11}{24}e^4-\frac{85}{8}\gamma^4e^2+\frac{35}{16}\gamma^2e^4+\frac{17}{192}e^6\right)\sin 2l$$

$$+\left(-\gamma^2-\gamma^4-\frac{9}{4}\gamma^2e^2-\gamma^6-\frac{89}{4}\gamma^4e^2+\frac{165}{16}\gamma^2e^4\right)\sin(2g+2l)$$

$$+\frac{99}{64}\gamma^2e^4\sin(2g-2l)+\frac{39}{16}\gamma^4e^2\sin(4g+2l)$$

$$+\frac{125}{64}e'^2\frac{a^2}{a'^2}\sin(2\chi+2l)+\left(\frac{25}{8}ee'-\frac{265}{24}\gamma^2ee'+\frac{135}{16}e^3e'+\frac{25}{8}ee'^3\right)\frac{a}{a'}\sin(\chi+2l)$$

$$+\frac{805}{96}e^3e'\frac{a}{a'}\sin(\chi-2l)-\frac{75}{16}\gamma^2ee'\frac{a}{a'}\sin(\chi+2g+2l)-\frac{35}{24}\gamma^2ee'\frac{a}{a'}\sin(\chi-2g-2l)$$

$$+\left(\frac{13}{12}e^3-\frac{5}{2}\gamma^2e^3-\frac{43}{64}e^5-\frac{165}{8}\gamma^4e^3+5\gamma^2e^5\right)\sin 3l$$

$$+\left(-2\gamma^2e-2\gamma^4e-\frac{11}{8}\gamma^2e^3-2\gamma^6e-\frac{49}{2}\gamma^4e^3+\frac{881}{64}\gamma^2e^5\right)\sin(2g+3l)$$

$$+\frac{1357}{640}\gamma^2e^5\sin(2g-3l)$$

$$+\left(3\gamma^4e+21\gamma^6e-\frac{105}{16}\gamma^4e^3\right)\sin(4g+3l)$$

$$+\frac{325}{64}ee'^2\frac{a^2}{a'^2}\sin(2\chi+3l)$$

$$+\left(\frac{65}{16}e^2e'-\frac{895}{48}\gamma^2e^2e'+\frac{315}{32}e^4e'\right)\frac{a}{a'}\sin(\chi+3l)$$

$$+\frac{2815}{256}e^4e'\frac{a}{a'}\sin(\chi-3l)$$

$$+\left(-\frac{5}{2}\gamma^2e'+5\gamma^4e'-\frac{245}{16}\gamma^2e^2e'\right)\frac{a}{a'}\sin(\chi+2g+3l)-\frac{505}{48}\gamma^2e^2e'\frac{a}{a'}$$

$$\sin(\chi-2g-3l)-\frac{5}{6}\gamma^4e'\frac{a}{a'}\sin(\chi-4g-3l).$$

The expression in purely elliptic motion is

$$\left(2e_0-\frac{1}{4}e_0^3+\frac{5}{96}e_0^5\right)\sin l_0+\left(2\gamma_0^2e_0+2\gamma_0^4e_0-\frac{7}{4}\gamma_0^2e_0^3+2\gamma_0^6e_0\right.$$

$$\left.-\frac{7}{4}\gamma_0^4e_0^3+\frac{5}{96}\gamma_0^2e_0^5\right)\sin(2g_0+l_0)$$

$$+\left(-\frac{1}{12}\gamma_0^2e_0^3-\frac{1}{12}\gamma_0^4e_0^3-\frac{5}{192}\gamma_0^2e_0^5\right)\sin(2g_0-l_0)-\frac{17}{12}\gamma_0^4e_0^3\sin(4g_0+l_0)$$

$$+\left(\frac{5}{4}e_0^2-\frac{11}{24}e_0^4+\frac{17}{192}e_0^6\right)\sin 2l_0+\left(-\gamma_0^2-\gamma_0^4+4\gamma_0^2e_0^2-\gamma_0^6+4\gamma_0^4e_0^2\right.$$

$$\left.-\frac{55}{16}\gamma_0^2e_0^4\right)\sin(2g_0+2l_0)-\frac{1}{24}\gamma_0^2e_0^4\sin(2g_0-2l_0)+\frac{11}{4}\gamma_0^4e_0^2$$

$$\sin(4g_0+2l_0)$$

$$+\left(\frac{13}{12}e_0^3-\frac{43}{64}e_0^5\right)\sin 3l_0+\left(-2\gamma_0^2e_0-2\gamma_0^4e_0+\frac{27}{4}\gamma_0^2e_0^3-2\gamma_0^6e_0+\frac{27}{4}\gamma_0^4e_0^3\right.$$

$$\left.-\frac{207}{32}\gamma_0^2e_0^5\right)\sin(2g_0+3l_0)-\frac{9}{320}\gamma_0^2e_0^5\sin(2g_0-3l_0)+\left(-2\gamma_0^4e_0\right.$$

$$\left.-4\gamma_0^6e_0+\frac{45}{4}\gamma_0^4e_0^3\right)\sin(4g_0+3l_0).$$

where only the terms of the same speed as before are retained. A suffix zero has been placed after e_0, γ_0, g_0, l_0 in this expression, $l-l_0$ is constant and small, but there is no reason why it should be zero.

Beginning with the terms whose speed is the mean motion and retaining terms of the third order only, we get

$$\left(2e-\frac{1}{4}e^3\right)\sin l-3\gamma^2e\sin(2g+l)+\frac{5}{2}e'\frac{a}{a'}\sin(\chi+$$

$$=\left(2e_0-\frac{1}{4}e_0^3\right)\sin l_0+2\gamma_0^2e_0\sin(2g_0+l$$

As a first approximation

$$e\sin l=e_0\sin l_0.$$

In time $\pi/2n$, we have

$$e\sin(l+\pi/2)=e_0\sin(l_0+\pi/2)$$

or

$$e\cos l=e_0\cos l_0.$$

As a general rule we may in any equation change sines into cosines, changing the sign of the coefficient, however, when the coefficient of l or l_0 is negative.

On referring to the equation obtained by equating terms containing $2l$, $2l_0$, we find that we commit an error of the fourth order in replacing

$$\gamma_0^2 \sin(2g_0+2l_0)$$

by

$$\gamma^2 \sin(2g+2l)$$

It follows that e_0-e, $\gamma_0^2-\gamma^2$, l_0-l, g_0-g, are respectively of the third, fourth, second and second orders, and hence in any equation we may drop the suffixes in the terms of the highest order retained.

We therefore at once obtain as a second approximation

$$e_0 \sin l_0 = e \sin l - \frac{5}{2}\gamma^2 e \sin(2g+l) + \frac{5}{4}e'\frac{a}{a'}\sin(\chi+l) \quad . \quad . \quad . \quad (1)$$

Again, from the terms whose speed is equal to twice the mean motion, we get correctly to the fourth order.

$$\left(\frac{5}{4}e^2 - \frac{5}{4}\gamma^2 e^2 - \frac{11}{24}e^4\right)\sin 2l + \left(-\gamma^2-\gamma^4-\frac{9}{4}\gamma^2 e^2\right)\sin(2g+2l)$$

$$+\frac{25}{8}ee'\frac{a}{a'}\sin(\chi+l) = \left(\frac{5}{4}e_0^2 - \frac{11}{24}e_0^4\right)\sin 2l_0 + (-\gamma_0^2-\gamma_0^4+4\gamma_0^2 e_0^2)$$
$$\sin(2g_0+2l_0)$$

We deduce from (1) and the corresponding formula where cosines replace sines,

$$e_0^2 \sin 2l_0 = e^2 \sin 2l - 5\gamma^2 e^2 \sin(2g+2l) + \frac{5}{2}ee'\frac{a}{a'}\sin(\chi+2l)$$

Whence

$$\gamma_0^2 \sin(2g_0+2l_0) = \gamma^2 \sin(2g+2l) + \frac{5}{4}\gamma^2 e^2 \sin 2l \quad . \quad . \quad . \quad (2)$$

From (1) we deduce

$$e_0^2 = e^2 - 5\gamma^2 e^2 \cos 2g + \frac{5}{2}ee'\frac{a}{a'}\cos\chi$$

and from (2),

$$\gamma_0^2 = \gamma^2 + \frac{5}{4}\gamma^2 e^2 \cos 2g$$

We must now return to the first equation and retain the terms of the fifth order, and approximate to the terms of the third order as far as the fifth order, by means of the results already obtained. We then return to the second equation and approximate as far as the sixth order. We thus obtain,

$$e_0 \sin l_0 = e \sin l - \frac{5}{2}\gamma^2 e \sin(2g+l)$$

$$+\frac{5}{4}e'\frac{a}{a'}\sin(\chi+l)$$

$$+\left(\frac{5}{2}\gamma^4 e-\frac{5}{4}\gamma^2 e^3\right)\sin l$$

$$+\left(-10\gamma^4 e+\frac{65}{16}\gamma^2 e^3\right)\sin(2g+l)$$

$$+\frac{15}{16}\gamma^2 e^3\sin(2g-l)$$

$$+\left(-\frac{15}{4}\gamma^2 e'+\frac{65}{16}e^2 e'+\frac{5}{4}e'^3\right)\frac{a}{a'}\sin(\chi+l)$$

$$+\frac{25}{8}e^2 e'\frac{a}{a'}\sin(\chi-l)+\frac{5}{3}\gamma^2 e'\frac{a}{a'}\sin(\chi-2g-l)$$

and

$$\gamma_0^2\sin(2g_0+2l_0)=\gamma^2\sin(2g+2l)+\frac{5}{4}\gamma^2 e^2\sin 2l$$

$$+\left(5\gamma^4 e^2-\frac{5}{16}\gamma^2 e^4\right)\sin 2l+\left(\frac{5}{4}\gamma^4 e^2-\frac{5}{32}\gamma^2 e^4\right)\sin(2g+2l)$$

$$-\frac{25}{64}\gamma^2 e^4\sin(2g-2l)-\frac{5}{2}\gamma^4 e^2\sin(4g+2l)$$

$$+\frac{5}{3}\gamma^2 ee'\frac{a}{a'}\sin(\chi+2l)+\frac{15}{8}\gamma^2 ee'\frac{a}{a'}\sin(\chi+2g+2l)$$

$$+\frac{5}{8}\gamma^2 ee'\frac{a}{a'}\sin(\chi-2g-2l).$$

In both of which equations we may replace sines by cosines, changing signs where necessary. As a verification, we substitute these values in the terms of the elliptic expression, whose speed is three times the mean motion. These terms are,

$$\frac{13}{12}e_0^3\sin 3l_0-2\gamma_0^2 e_0\sin(2g_0+3l_0)-\frac{43}{64}e_0^5\sin 3l_0$$

$$+\left(-2\gamma_0^4 e_0+\frac{27}{4}\gamma_0^2 e_0^3\right)\sin(2g_0+3l_0)$$

$$-2\gamma_0^4 e_0\sin(4g_0+3l_0)$$

$$+\left(-2\gamma_0^6 e_0+\frac{27}{4}\gamma_0^4 e_0^3-\frac{207}{32}\gamma_0^2 e_0^5\right)\sin(2g_0+3l_0)$$

$$-\frac{9}{320}\gamma_0^2 e_0^5\sin(2g_0-3l_0)+\left(-4\gamma_0^6 e_0+\frac{45}{4}\gamma_0^4 e_0^3\right)\sin(4g_0+3l_0).$$

They become, after the substitutions have been performed,

$$\frac{13}{12}e^3\sin 3l-2\gamma^2 e\sin(2g+3l)$$

$$+\left(-\frac{5}{2}\gamma^2 e^3-\frac{43}{64}e^5\right)\sin 3l$$

$$+\left(-2\gamma^4 e-\frac{11}{8}\gamma^2 e^3\right)\sin(2g+3l)$$

$$+3\gamma^4 e\sin(4g+3l)$$

$$+\frac{65}{16}e^2e'\frac{a}{a'}\sin(\chi+3l)-\frac{5}{2}\gamma^2 e'\frac{a}{a'}\sin(\chi+2g+3l)$$

$$+\left(-\frac{165}{8}\gamma^4 e^3+5\gamma^2 e^5\right)\sin 3l$$

$$+\left(-2\gamma^6 e-\frac{49}{2}\gamma^4 e^3+\frac{881}{64}\gamma^2 e^5\right)\sin(2g+3l)$$

$$+\frac{1357}{640}\gamma^2 e^5\sin(2g-3l)$$

$$+\left(21\gamma^6 e-\frac{105}{16}\gamma^4 e^3\right)\sin(4g+3l)$$

$$+\frac{325}{64}ee'^2\left(\frac{a}{a'}\right)^2\sin(2\chi+3l)$$

$$+\left(-\frac{895}{48}\gamma^2 e^2 e'+\frac{315}{32}e^4 e'+\frac{65}{16}e^2 e'^3\right)\frac{a}{a'}\sin(\chi+3l)$$

$$+\frac{2815}{256}e^4 e'\frac{a}{a'}\sin(\chi-3l)$$

$$+\left(5\gamma^4 e'-\frac{245}{16}\gamma^2 e^2 e'-\frac{5}{2}\gamma^2 e'^3\right)\frac{a}{a'}\sin(\chi+2g+3l)$$

$$-\frac{505}{48}\gamma^2 e^2 e'\frac{a}{a'}\sin(\chi-2g-3l)-\frac{5}{6}\gamma^4 e'\frac{a}{a'}\sin(\chi-4g-3l).$$

Delaunay omits the two terms

$$\frac{65}{16}e^2 e'^3\frac{a}{a'}\sin(\chi+3l)-\frac{5}{2}\gamma^2 e'^3\frac{a}{a'}\sin(\chi+2g+3l).$$

which he considers as being of the eighth order, on account of the smallness of e'. With this exception the expression just obtained agrees with the corresponding terms of Delaunay's expression. This verifies the algebraical work. Squaring and adding the expressions for $e_0\sin l_0$, $e_0\cos l_0$.

$$e_0{}^2=e^2-5\gamma^2 e^2\cos 2g+\frac{5}{2}ee'\frac{a}{a'}\cos\chi$$

$$+\frac{45}{4}\gamma^4 e^2-\frac{5}{2}\gamma^2 e^4+\frac{25}{16}e'^2\frac{a^2}{a'^2}$$

$$+\left(-20\gamma^4 e^2+\frac{25}{4}\gamma^2 e^4\right)\cos 2g$$

$$+\left(-\frac{15}{2}\gamma^2 ee'+\frac{15}{8}e^3 e'+\frac{5}{2}ee'^3\right)\frac{a}{a'}\cos\chi$$

$$-\frac{115}{12}\gamma^2 ee'\frac{a}{a'}\cos(\chi-2g).$$

Again, from the expressions for

$$\gamma_0^2 \sin(2g_0+2l_0),\ \gamma_0^2 \cos(2g_0+2l_0),$$

$$\gamma_0^2 \cos(2g_0+2l_0-2g-2l) = \gamma^2 + \frac{5}{4}\gamma^2 e^2 \cos 2g$$

$$+\left(\frac{5}{4}\gamma^4 e^2 - \frac{5}{32}\gamma^2 e^4\right) + \left(\frac{5}{2}\gamma^4 e^2 - \frac{5}{16}\gamma^2 e^4\right)\cos 2g$$

$$+\frac{25}{64}\gamma^2 e^4 \cos 4g + \frac{5}{4}\gamma^2 ee'\frac{a}{a'}\cos\chi$$

$$+\frac{5}{3}\gamma^2 ee'\frac{a}{a'}\cos(\chi-2g)$$

and

$$\gamma_0^2 \sin(2g_0+2l_0-2g-2l) = -\frac{5}{4}\gamma^2 e^2 \sin 2g$$

$$\therefore\ \gamma_0^2(1-\cos(2g_0+2l_0-2g-2l)) = \frac{25}{64}\gamma^2 e^4(1-\cos 4g)$$

$$\therefore\ \gamma_0^2 = \gamma^2 + \frac{5}{4}\gamma^2 e^2 \cos 2g + \left(\frac{5}{4}\gamma^4 e^2 + \frac{15}{64}\gamma^2 e^4\right)$$

$$+\left(\frac{5}{2}\gamma^4 e^2 - \frac{5}{16}\gamma^2 e^4\right)\cos 2g + \frac{5}{4}\gamma^2 ee'\frac{a}{a'}\cos\chi$$

$$+\frac{5}{3}\gamma^2 ee'\frac{a}{a'}\cos(\chi-2g).$$

Correctly, therefore, to the fourth order e_0^2 must lie between

$$e^2 \pm 5\gamma^2 e^2 + 5ee'\frac{a}{a'}$$

and γ_0^2 between

$$\gamma^2 \pm \frac{5}{4}\gamma^2 e^2$$

This result bears some resemblance to planetary theory.

The conditions of the problem would be approximately realised for a small satellite of *Neptune's* revolving near the surface of its primary.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1893, *deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.*

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lv. p. 150, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1893, and Table II. gives the same particulars for the entire year 1893 and for the four preceding years for the sake of comparison. The areas are given in two forms. First, projected areas—that is to say, as seen and measured on the photographs—these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1893 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results for 1889, 1890, 1891, and 1892 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888, on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Projected. Faculæ.	Corr. for Foreshortening. Umbræ.	Corr. for Foreshortening. Whole Spots.	Corr. for Foreshortening. Faculæ
	1892.							
525	Dec. 27·20	28	191	1190	1965	134	856	2096
	1893.							
526	Jan. 23·53	27	343	2122	2360	249	1571	2430
527	Feb. 19·87	26	223	1256	2092	154	907	2236
528	Mar. 19·20	28	228	1496	2290	162	1114	2367
529	Apr. 15·48	27	296	1886	2477	202	1342	2518
530	May 12·72	27	285	1959	2897	203	1456	2955
531	June 8·92	26	190	1329	2691	144	1085	2844
532	July 6·12	27	344	2150	2628	244	1574	2755
533	Aug. 2·33	28	532	3215	2949	381	2383	3152
534	Aug. 29·57	27	428	2544	2286	303	1802	2460
535	Sept. 25·84	27	335	1799	2313	253	1411	2458
536	Oct. 23·13	27	302	1662	1629	212	1197	1685
537	Nov. 19·43	28	319	2075	1259	233	1514	1351

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corr. for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404

TABLE III.

No of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	1892.							
525	Dec. 27·20	28	183	+15·20	674	−16·91	−10·06	16·55
	1893.							
526	Jan. 23·53	27	318	+16·84	1253	−16·69	− 9·91	16·72
527	Feb. 19·87	26	411	+11·42	497	−14·52	− 2·79	13·12
528	Mar. 19·20	28	478	+15·63	636	−14·82	− 1·77	15·17
529	Apr. 15·48	27	580	+17·26	762	−16·90	− 2·13	17·06
530	May 12·72	27	453	+17·25	1002	−18·58	− 7·42	18·16
531	June 8·92	26	262	+14·35	822	−16·71	− 9·21	16·14
532	July 6·12	27	607	+14·44	967	−17·10	− 4·95	16·08
533	Aug. 2·33	28	632	+14·93	1751	−16·08	− 7·87	15·78
534	Aug. 29·57	27	538	+12·23	1264	−11·72	− 4·57	11·87
535	Sept. 25·84	25*	842	+12·04	474	−12·40	+ 3·23	12·17
536	Oct. 23·13	27	389	+15·18	808	− 8·30	− 0·67	10·54
537	Nov. 19·43	28	781	+18·52	733	− 7·06	+ 6·14	12·98

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1889	360	5·0	+ 7°·26	73·0	−11·90	−10·68	11°·61
1890	361	53·1	+22·20	46·3	−21·75	+ 1·73	21·99
1891	363	401	+20·49	169	−19·91	+ 8·52	20·31
1892	362	607	+15·09	607	−21·69	− 3·29	18·39
1893	360*	517	+14·91	941	−14·26	− 3·93	14·49

The principal features of the sun-spot record for 1893, as brought out by the above tables, are :—

(1) The increase in the mean daily area of umbræ and whole spots has been still continued, but in a greatly diminished ratio.

* The photographs on two days, October 20 and 22, have been used for the areas of the sun-spots, but not for their positions.

(2) But the mean daily area of the faculæ has undergone a notable decline.

(3) The predominance as to spotted area has changed over definitely from the northern hemisphere to the southern.

(4) The mean daily spotted area has actually declined for the northern hemisphere as compared with 1892, the increase recorded for the whole disc being entirely due to the great activity of the southern hemisphere.

(5) The mean distance from the equator of all spots has reached the zone usually occupied at maximum, and, indeed, for the last four rotations of the year, has considerably overpassed it. The extraordinary outburst of 1893 August, which was followed so promptly by this decline in latitude, probably marks, therefore, the actual crest of the curve at maximum.

(6) The decline in latitude has been mainly witnessed in the southern hemisphere, and set in, as just stated, immediately after the close of the great outburst for that hemisphere in August.

(7) On the whole the maximum as to spotted area appears to have fallen in 1893 August, both for the southern hemisphere and for the Sun as a whole. For the northern hemisphere considered separately, it seems to have fallen nearly fourteen months earlier, towards the end of June or beginning of July 1892.

Royal Observatory, Greenwich:
1895 *October* 28.

Diameters of Saturn and his Rings, observed at the Royal Observatory, Greenwich, during the Opposition of 1895.

(*Communicated by the Astronomer Royal.*)

Measures of *Saturn's* rings and of equatorial and polar diameters were made with the filar micrometer on the 28-inch refractor during the months of April, May, and June 1895, the full aperture being used in all cases.

The distances of the edge of the outer ring, of the centre of Cassini's division, of the edge of the inner bright ring, and of the crape ring were measured from the nearer and further limbs of the planet, both on the preceding and following sides; the mean of two such measures giving the radius of a ring, and the difference giving the equatorial diameter of *Saturn*. Direct measures were also made of the polar diameter and of the width of Cassini's division. The latter was sharply defined, and was easy to measure, and seemed a little more distinct on the following than on the preceding side. Encke's division was seen at both ansæ on June 12 by the Astronomer Royal and Mr. Lewis.

The results obtained on the separate nights are given in the following table, as well as the number of separate determinations of each result. In the column "Observer" D denotes Mr. Dyson, and L Mr. Lewis. The measures have all been reduced to a mean distance of 9·53885, and the polar diameters have been corrected for the elevation of the earth above the plane of the ring.

Date.	Observer.	Power.	Diameters of *Saturn*. Equatorial.	Polar.	Outer radius of Outer Ring. Preceding.	Following.	Width of Cassini's Division. Preceding.	Following.	Radius to centre of Cassini's Division. Preceding.	Following.	Inner radius of Inner Bright Ring. Preceding.	Following.	Inner radius of Crape Ring. Preceding.	Following.
1895.			″	″	″			″	″	″	′	′	′	″
Apr. 13	L.	670	17·56$_{20}$	...	20·12$_{10}$	20·18$_{10}$	...	...	...	...	...	...	...	...
14	D.	670	·71$_{19}$	16·72$_{7}$	·40$_{6}$	·17$_{3}$	...	...	17·22$_{7}$	17·17$_{4}$	12·48$_{6}$	...	...	...
23	L.	670	·92$_{48}$	17·20$_{7}$	·40$_{8}$	·26$_{8}$	0·53$_{4}$	0·61$_{4}$	·27$_{8}$	·37$_{8}$	·94$_{8}$	12·85$_{8}$	10·53$_{8}$	10·38$_{8}$
28	D.	670	·67$_{50}$	15·91$_{10}$	·09$_{8}$	·09$_{8}$	·49$_{4}$	·55$_{4}$	·11$_{8}$	·12$_{8}$	·45$_{8}$	·42$_{10}$	...	...
29	L.	670	·71$_{32}$	...	·13$_{8}$	·17$_{8}$	·52$_{4}$	·55$_{4}$	·19$_{8}$	·42$_{8}$	·86$_{6}$	13·00$_{6}$	·76$_{6}$	·50$_{6}$
May 11	L.	670	·71$_{22}$	16·71$_{11}$	·36$_{4}$	·26$_{6}$	·46$_{4}$	·48$_{4}$	·09$_{6}$	·19$_{6}$	13·01$_{6}$	12·89$_{6}$	...	...
13	L.	670	·79$_{10}$	17·02$_{9}$	...	...	...	...	...	...	...	...	...	...
31	L.	670	·88$_{20}$	...	·37$_{10}$	·53$_{10}$	·62$_{4}$	·44$_{2}$	17·13$_{6}$	...	...	...	·21$_{4}$	9·98$_{4}$
June 2	D.	480	...	...	...	...	·46$_{7}$	·41$_{6}$	...	...	...	...	...	...
6	L.	480	·81$_{10}$	...	·42$_{5}$	·53$_{5}$	...	...	...	...	...	...	...	...
7	L.	670	17·74$_{12}$	17·20$_{10}$	·06$_{6}$	·45$_{6}$	·40$_{4}$	·44$_{4}$	16·80$_{6}$	17·13$_{6}$	13·02$_{6}$	13·11$_{6}$	·20$_{4}$	10·13$_{4}$
12	L.	670	18·01$_{15}$	...	·26$_{5}$	...	·54$_{6}$	·65$_{6}$	...	...	...	...	·09$_{6}$	·03$_{6}$
18	L.	670	...	...	...	...	·51$_{4}$	·55$_{4}$	...	...	...	...	...	...
26	L.	670	17·53$_{6}$	...	20·27$_{4}$	20·64$_{4}$	0·54$_{4}$	0·67$_{3}$	...	...	...	...	10·42$_{2}$	10·35$_{2}$
Mean			17·754$_{254}$	16·793$_{54}$	20·262$_{74}$	20·328$_{70}$	0·507$_{45}$	0·535$_{37}$	17·116$_{49}$	17·233$_{40}$	12·793$_{40}$	12·854$_{36}$	10·368$_{30}$	10·397$_{30}$

In addition to this, the position-angle of the major axis of the rings was measured with the following results :—

Date.	Position-angle of Major Axis.	Date.	Position-angle of Major Axis.
	° ′		° ′
Apr. 13	359 24	June 6	358 38
14	358 2	7	359 20
23	360 18	12	360 0
29	359 24	18	361 20
May 11	359 23	20	361 15
13	359 22	26	360 10
31	359 15		

The diameter of *Titan* was measured on three nights as follows :—

Date.	Diameter of *Titan.*	No. of Measures.
	″	
Apr. 23	0·990	6
May 11	0·828	11
June 12	1·028	4
	0·950	21

The mean results of the measures are given below, together with those obtained by Professor Hall at Washington 1885–1887, and by Professor Barnard at the Lick Observatory, Mount Hamilton, in 1895.

	Greenwich.	Mt. Hamilton.	Washington.
	″	″	″
Equatorial diameter of Saturn ...	17·754	17·744	17·72
Polar diameter of Saturn	16·793	16·307	...
Outer diameter of Outer Ring ...	40·590	40·249	40·45
Inner diameter of Outer Ring ...	34·870	34·864	34·95
Centre of Cassini's Division ...	34·349	34·306	34·53
Outer diameter of Inner Ring ...	33·828	33·748	34·11
Inner diameter of Inner Ring ...	25·647	25·522	25·75
Inner diameter of Crape Ring ...	20·765	20·737	20·52
Width of Cassini's Division ...	0·521	0·558	0·42
Width of Outer Ring	2·860	2·693	2·750
Width of Inner Ring	4·091	4·113	4·180
Width of Crape Ring	2·382	2·393	2·625

The following table, based on 92,797,000 miles, as mean distance of the Earth from the Sun, gives the actual dimensions of *Saturn's* system as determined at these three observatories :—

	Greenwich. (miles)	Mt. Hamilton. (miles)	Washington. (miles)
Equatorial diameter of Saturn ...	76,190	76,150	76,050
Polar diameter of Saturn	72,066	69,980	...
Outer diameter of Outer Ring ...	174,190	172,730	173,590
Inner diameter of Outer Ring ...	149,640	149,620	149,990
Outer diameter of Inner Ring ...	145,170	144,830	146,380
Inner diameter of Inner Ring ...	110,060	109,530	110,500
Inner diameter of Crape Ring ...	89,110	88,990	88,060
Width of Cassini's Division ...	2,240	2,400	1,800
Width of Outer Ring	12,270	11,560	11,800
Width of Inner Ring	17,560	17,650	17,940
Width of Crape Ring	10,220	10,270	11,260

The agreement of the Greenwich, Mount Hamilton, and Washington results is very satisfactory, except in the case of the polar diameter, of which a comparatively small number of measures were made at Greenwich. If the low declination of the planet permits, it is intended to supplement these by more measures of the polar diameter at the next opposition.

Meridian Observations of Sirius and Procyon at the Royal Observatory, Greenwich, 1836–1894. By W. G. Thackeray.

In reducing a long series of observations such as the above to a common epoch, it is very essential to make the reductions on as homogeneous a system as possible, a matter of no little difficulty and trouble.

The following right ascensions were made with the transit instrument from 1836–1850, and with the transit circle from 1851–1894.

The difficulty of adjusting the observed right ascensions of stars to a fixed point—the point where the Sun crosses the Equator at the spring equinox—has been met by correcting the adopted places of those stars which have been used to ascertain the errors of the transit clock in accordance with the quantities given annually in the "Greenwich Observations" under the section of discussions of the position of the Ecliptic—a correction which for brevity we may refer to as the correction to the equinox. The opportunity for making such a correction has always been chosen at the time of making one of the periodical catalogues, and reference to the introduction to any of these catalogues will show the method observed.

In this investigation the equinox of the 1880 catalogue has been adopted as the standard of reference in forming the adopted right ascensions for 1890.

The following table gives the necessary corrections and the

data on which they are founded. The first column, (1), gives the years corresponding to the various catalogues. The second column, (2), gives the authority for the places of the clock-star list as adopted in the reductions. For instance, in 1836 the authority was a catalogue of star places given in the *Nautical Almanac* for 1834, 2nd edition; and this catalogue as corrected by quantities given in the introductions to the "Greenwich Observations" was used till 1843, when the places of the Greenwich 1840 Catalogue were used; and these were used until 1849, when the places of the Greenwich 1845 Catalogue were used, and so on. The third column, (3), gives the corrections that are required to bring the clock-star system used in the reductions of different years to a uniform system for each catalogue. Column (4) gives the apparent correction to the equinox for the series of years forming the catalogue from the observation of the Sun as depending on the system of clock stars used for each year's reductions. Column (5) is the mean of the corrections taking column (4)–column (3) for each catalogue. Column (6) gives the correction to the equinox for each year after the clock stars have been reduced to a uniform system, and is the sum of columns (5) and (3). Column (7) is the mean of the corrections in column (6) for the series of years forming the different catalogues, and which may be taken as the systematic catalogue correction to the adopted clock-star places. Column (8) is the correction to the various catalogues to reduce them to the adopted equinox of the 1880 catalogue, and column (9), which is the sum of (6) and (8), gives the correction required to reduce the mean right ascensions of each individual year to the equinox of the 1880 catalogue—that is to say, what the observed right ascension would have been had the standard right ascensions of the Ten-year Catalogue 1880 been used throughout as the authority for the annual clock-star lists, always assuming the validity of the so-called correction to the equinox.

Corrections required to reduce Mean Right Ascensions of the Annual Catalogues of the Greenwich Observations to the Equinox of the 1880 Catalogue.

TABLE I.

Year.	Authority for Clock-Star List.	Correction to adopted Clock-Star System.	Apparent Correction to Equinox.	Assumed Correction to Equinox.	Adopted Correction to Equinox for Annual Mean R.A.'s.	Resulting Mean Correction to Catalogue.	Correction to reduce Catalogues to Equinox of 1880 Cat.	Correction to reduce Annual Mean R.A.'s to Equinox of 1880 Cat.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		s	s	s	s	s	s	s
1836	Catalogue in	+ ·029	− ·130		− ·081			− ·052
1837	N.A. 1834, 2nd edition,	+ ·034	− ·048		− ·076			− ·047
1838	corrected by	+ ·024	− ·137		− ·086			− ·057
1839	quantities given in in-	+ ·025	− ·074	− ·110	− ·085	− ·084	+ ·029	− ·056
1840	troductions	+ ·022	− ·089		− ·088			− ·059
1841	to Greenwich observations	+ ·020	− ·026		− ·090			− ·061

Year.	Authority for Clock-Star List.	Correction to adopted Clock-Star System.	Apparent Correction to Equinox.	Assumed Correction to Equinox.	Adopted Correction to Equinox for Annual Mean R.A.'s.	Resulting Mean Correction to Catalogue.	Correction to reduce Catalogues to Equinox of 1880 Cat.	Correction to reduce Annual Mean R.A.'s to Equinox of 1880 Cat.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		s	s	s	s	s	s	s
1842		+ ·022	−·061		−·021			−·076
1843	1840 Cat.	+ ·111	+·101		+·068			+·013
1844		+ ·099	+·010	−·043	+·056	+·045	−·055	+·001
1845		+ ·120	+·093		+·077			+·022
1846		+ ·081	+·087		+·038			−·017
1847		+ ·093	+·037		+·050			−·005
1848		+ ·062	+·186		+·072			+·062
1849	1845 Cat.		−·038		+·010			000
1850			−·064	+·010	+·010	+·020	−·010	000
1851			−·019		+·010			000
1852			+·033		+·010			000
1853			+·022		+·010			000
1854		+0·009	+·061		000			+·010
1855		+0·009	−·011		000			+·010
1856	1850 Cat.		−·068		−·010			000
1857			−·016	−·010	−·010	−·007	+·010	000
1858			−·025		−·010			000
1859			+·044		−·010			000
1860			−·019		−·010			000
1861		000	−·001					
1862	1860 Cat.		−·005					
1863			+·008					
1864			−·002	−·010	−·010	−·010	+·003	−·007
1865			−·010					
1866			−·006					
1867			−·051					
1868		000	−·050					
1869		000	−·001					
1870	1864 Cat.		−·012					
1871			+·044					
1872			−·019	+·007	+·007	+·007	−·007	000
1873			+·058					
1874			−·049					
1875			+·038					
1876			+·055					

Year.	Authority for Clock-Star List.	Correction to adopted Clock-Star System.	Apparent Correction to Equinox.	Assumed Correction to Equinox.	Adopted Correction to Equinox for Annual Mean R.A.'s.	Resulting Mean Correction to Catalogue.	Correction to reduce Catalogues to Equinox of 1880 Cat.	Correction to reduce Annual Mean R.A.'s to Equinox of 1880 Cat.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		s	s	s	s	s	s	s
1877		+ ·013	+ ·044		+ ·013			+ ·013
1878	1872 Cat.		− ·049					
1879			+ ·025					
1880			− ·092					
1881			− ·035					
1882			− ·027	000	000	+ ·000		000
1883			− ·002					
1884			+ ·084					
1885			− ·009					
1886			+ ·094					

The observations of north polar distances were made with the Jones and Troughton Circles for the years 1836–39, with the Troughton Circle 1840–47, with the Troughton and Jones Cape Circle for the year 1848, with the Troughton Circle for the years 1849–50, and with the Transit Circle 1851–94.

For the years 1836–47 the position of these circles was 0″·07 N. of the Transit Circle; 1848–50 the Troughton Circle was 0″·04 S. of the Transit Circle. See "Systematic Errors of the Greenwich Transit Circle," by W. H. M. Christie, *Memoirs R.A.S.* vol. xiv. pp. 156, 157.

The north polar distances for the years 1836–47 have been corrected to colatitude 21″·83; those of 1849–50 to colatitude 21″·94, and those of 1851–94 to colatitude 21″·90.

The following table (II.) exhibits the corrections which are necessary to be applied to the results of each year's observations, as given in the various annual catalogues of Greenwich observations, to reduce the observations of 1836–50 to Bessel's refractions and colatitude of the present Greenwich Transit Circle, 38° 31′ 21″·90, and the Transit Circle observations to the following system :—

Flexure=0″·00.
Bessel's refractions (*Tabulæ Regiomontanæ*).
Colatitude 38° 31′ 21″·90.
Formula of $R-D=a+b \sin z$.

In addition, corrections have also been applied to the results of the years 1868–76 for the wear of the microscope micrometer screws.

No corrections have been applied for Dr. Chandler's latitude variation.

TABLE II.

Corrections required to reduce Mean North Polar Distances of Sirius and Procyon in Annual Catalogues of the Greenwich Observations to a uniform system.

Year.	*Sirius.* Colatitude 21″·90 and Bessel's Refractions.	Flexure ·00 R−D a+b sin z.	Wear of Micro-scopes.	Sum.	*Procyon.* Colatitude 21″·90 and Bessel's Refractions.	Flexure ·00 R−D a+b sin z	Wear of Micro-scopes.	Sum.
	″	″	″	″	″	″	″	″
1836–38	−0·10	...	...	−0·10	−0·10	...	...	−0·10
1839	+0·16	...	...	+0·16	+0·16	...	...	+0·16
1840	+0·13	...	...	+0·13	+0·13	...	...	+0·13
1841–48	+0·03	...	...	+0·03	+0·03	...	...	+0·03
1849–50	+0·14	...	...	+0·14	+0·14	...	...	+0·14
1851–53	+0·10	...	...	+0·10	+0·10	...	...	+0·10
1854–60	−0·10	...	...	−0·10	−0·10	...	...	−0·10
1861	+0·10	...	...	+0·10	+0·10	...	...	+0·10
1862	+0·10	−0·34	...	−0·24	+0·10	−0·10	...	0·00
1863	+0·10	−0·40	...	−0·30	+0·10	−0·16	...	−0·06
1864	+0·10	−0·29	...	−0·19	+0·10	−0·10	...	0·00
1865	+0·10	−0·50	...	−0·40	+0·10	−0·16	...	−0·06
1866	+0·10	+0·52	...	+0·62	+0·10	+0·16	...	+0·26
1867	+0·10	+0·38	...	+0·48	+0·10	+0·14	...	+0·24
1868	+1·04	+0·60	+0·13	+1·77	+0·62	+0·20	0·00	+0·82
1869	+1·04	+0·53	+0·15	+1·72	+0·62	+0·20	+0·03	+0·85
1870	+1·04	+0·47	+0·04	+1·55	+0·62	+0·17	−0·05	+0·74
1871	+1·04	+0·47	+0·26	+1·77	+0·62	+0·17	+0·04	+0·83
1872	+1·04	+0·36	−0·08	+1·32	+0·62	+0·13	−0·04	+0·71
1873	+1·04	+0·40	+0·30	+1·74	+0·62	+0·14	−0·01	+0·75
1874	+1·04	+0·37	...	+1·41	+0·62	+0·13	...	+0·75
1875	+1·04	+0·21	...	+1·25	+0·62	+0·07	...	+0·69
1876	+1·04	+0·24	...	+1·28	+0·62	+0·08	...	+0·70
1877–94	...	...	...	0·00	...	...	...	0·00

The following table (III.) gives the mean observed right ascensions and north polar distances of *Sirius*, as taken from the annual catalogues of the Greenwich observations reduced to 1890 by the use of Peters' constants of precession, and corrected, by Tables I. and II., with (*a*) Professor Auwers' proper motions $-0^s\cdot0372$ and $+1''\cdot199$, and (*b*) corrected proper motion in N.P.D. of $+1''\cdot229$.

The following diagrams exhibit the finally adopted places for 1890, first of all compared with orbital corrections given by

Professor Auwers in the *Astr. Nachr.* No. 3085; and secondly, as corrected by the same quantities. And assuming that these latter are correct, then the Greenwich observations appear to show that a correction of $+0''\cdot030$ should be applied to Professor Auwers' value of the proper motion in N.P.D.

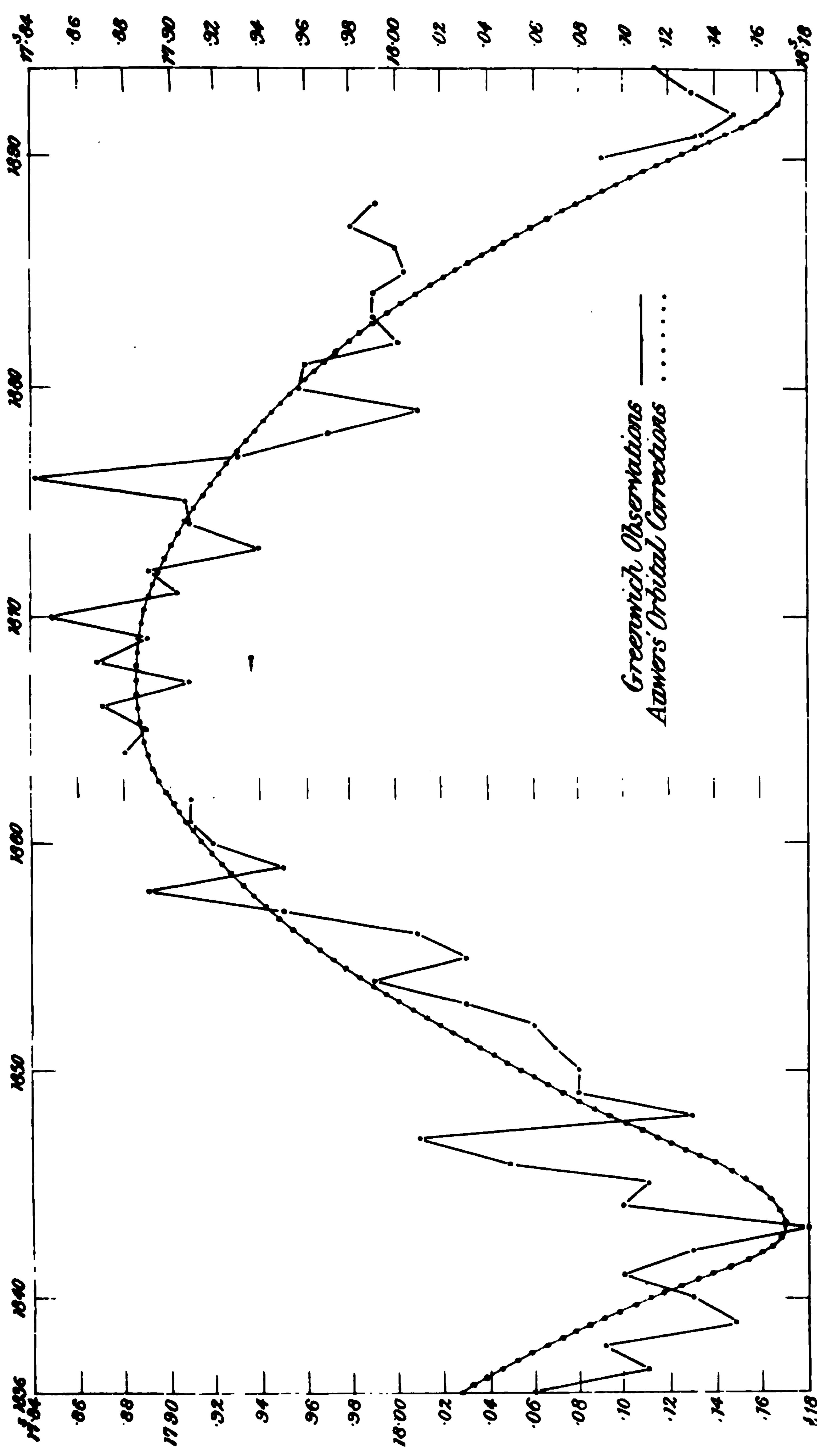
TABLE III.

Mean Right Ascensions and North Polar Distances of Sirius reduced to 1890·0, *with Peters' Constants of Precession and (a) Auwers' Proper Motion, (b) Corrected Proper Motion in N.P.D.*

Year and fraction of year.	Mean Right Ascension.	No. of Obs.	Adopted Seconds of R.A. 1890·0.	Year and fraction of year.	Mean North Polar Distance.	No. of Obs.	Adopted Seconds of N.P.D. 1890·0. (a)	(b)
	h m s		s		° ′ ″		″	″
1836·36	6 37 55·340	23	18·060	1836·31	106 29 48·91	28	57·48	59·10
1837·43	58·030	17	·110	1837·50	53·94	131	58·02	59·61
1838·34	38 0·660	21	·090	1838·44	58·19	30	57·77	59·33
1839·31	3·360	26	·150	1839·46	30 1·55	22	56·87	58·41
1840·25	6·010	30	·130	1840·48	6·22	17	57·00	58·50
1841·31	8·630	12	·100	1841·36	11·11	6	57·26	58·73
1842·39	11·320	32	·130	1842·45	14·77	11	56·38	57·82
1843·43	13·930	16	·180	1843·45	18·15	13	55·24	56·65
1844·50	16·510	13	·100	1844·49	22·49	9	55·06	56·44
1845·31	19·140	17	·110	1845·43	26·34	10	54·37	55·72
1846·29	21·770	27	·050	1846·40	31·05	10	54·54	55·86
1847·26	24·360	22	·010	1847·44	35·64	5	54·57	55·86
1848·30	27·030	27	·130	1848·39	40·12	11	54·82	56·08
1849·40	29·680	38	·080	1849·36	44·84	23	54·90	56·13
1850·32	32·330	21	·080	1850·31	50·23	25	55·65	56·85
1851·31	34·970	24	·070	1851·29	53·41	27	54·14	55·31
1852·30	37·600	29	·060	1852·30	58·54	26	54·62	55·76
1853·21	40·210	7	18·030	1853·26	31 3·34	8	55·74	56·85
1854·33	42·800	13	17·990	1854·37	8·04	15	54·97	56·05
1850·32	45·490	15	18·030	1855·37	12·61	16	54·97	56·02
1856·42	48·130	9	18·010	1856·42	17·46	9	55·24	56·26
1857·38	50·710	13	17·950	1857·39	23·00	12	56·20	57·19
1858·50	53·290	10	·890	1858·45	28·12	9	56·73	57·69
1859·34	55·990	11	·950	1859·34	32·05	11	56·07	57·00
1860·45	58·610	7	·920	1860·39	37·30	6	56·73	57·63
1861·38	39 1·240	9	·910	1861·44	40·75	8	55·89	56·76
1862·88	6 39 3·880*	2	·910	1862·57	106 31 47·21*	2	57·28	58·12

* One observation in this year's result has been rejected.

Right Ascensions of Sirius observed at the Royal Observatory, Greenwich, 1836-1894 reduced to 1890 with Auwers' proper motion; compared with Auwers' corrections for orbital motion. Astronomische Nachrichten No. 3085.



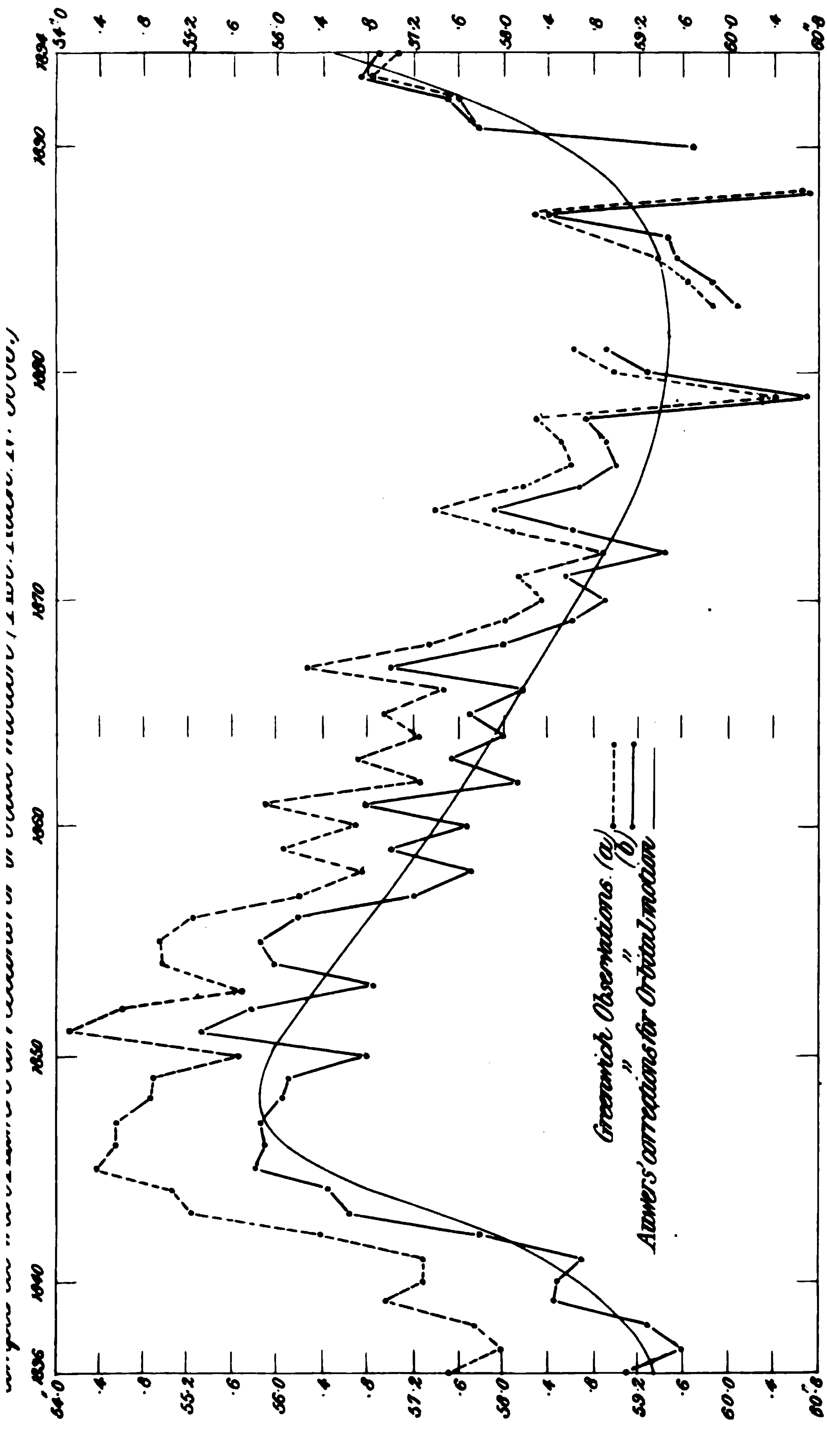
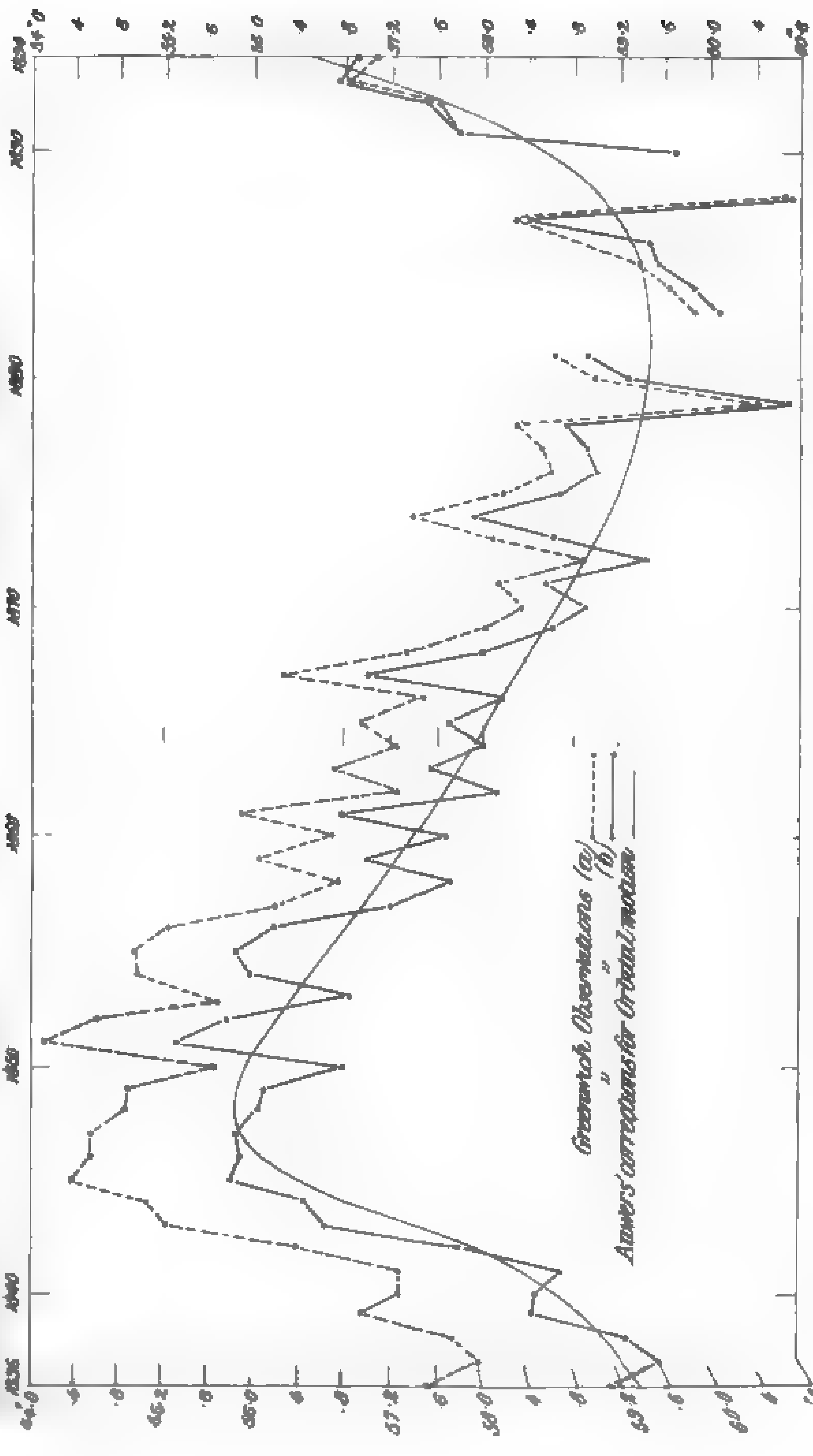

Greenwich Observations (a)
" (b)
Auwers' corrections for Orbital motion

DIAGRAM (2)

North Polar Distances of Sirius observed at the Royal Observatory, Greenwich 1836-1894 reduced to 1890 with (a) Auwers' Proper motion + 1".193; (b) adopted proper motion + 1".229; compared with Auwers corrections for orbital motion (Ast. Nach. No 3085.)



Right Ascensions of Sirius observed at the Royal Observatory, Greenwich, 1836–1894 reduced to 1890 with Auwers' correction for linear and orbital motions

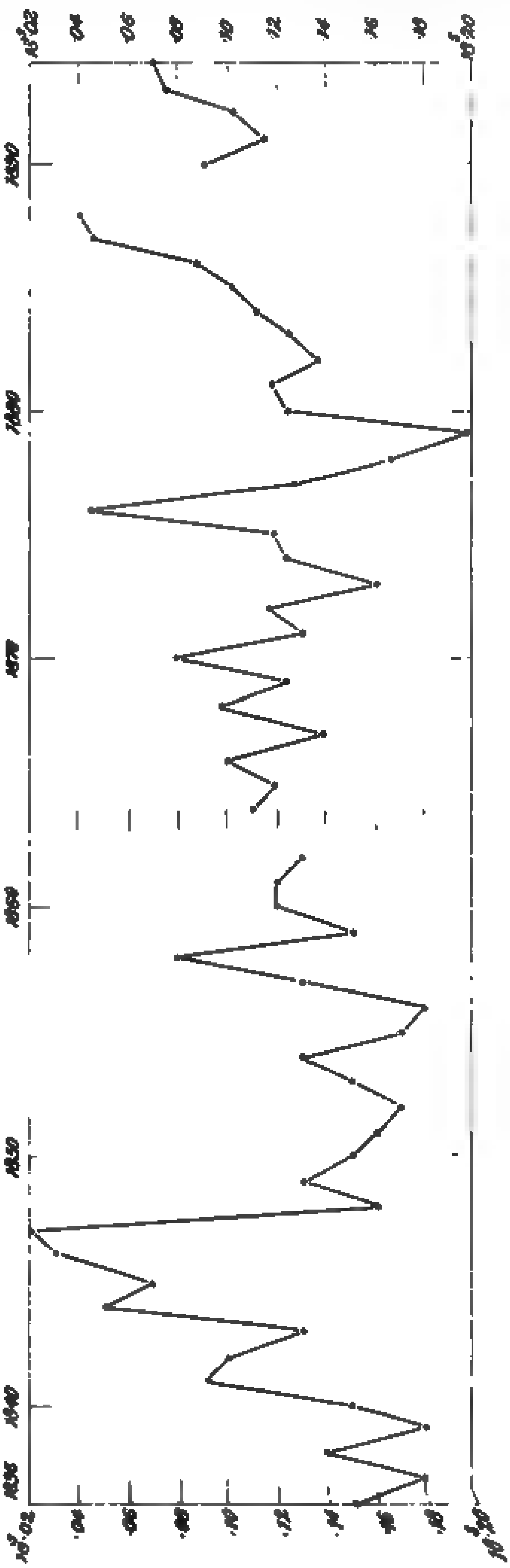


DIAGRAM (3)

Right Ascensions of Sirius observed at the Royal Observatory, Greenwich, 1836-1894 reduced to 1890 with Auwers' correction for linear and orbital motions.

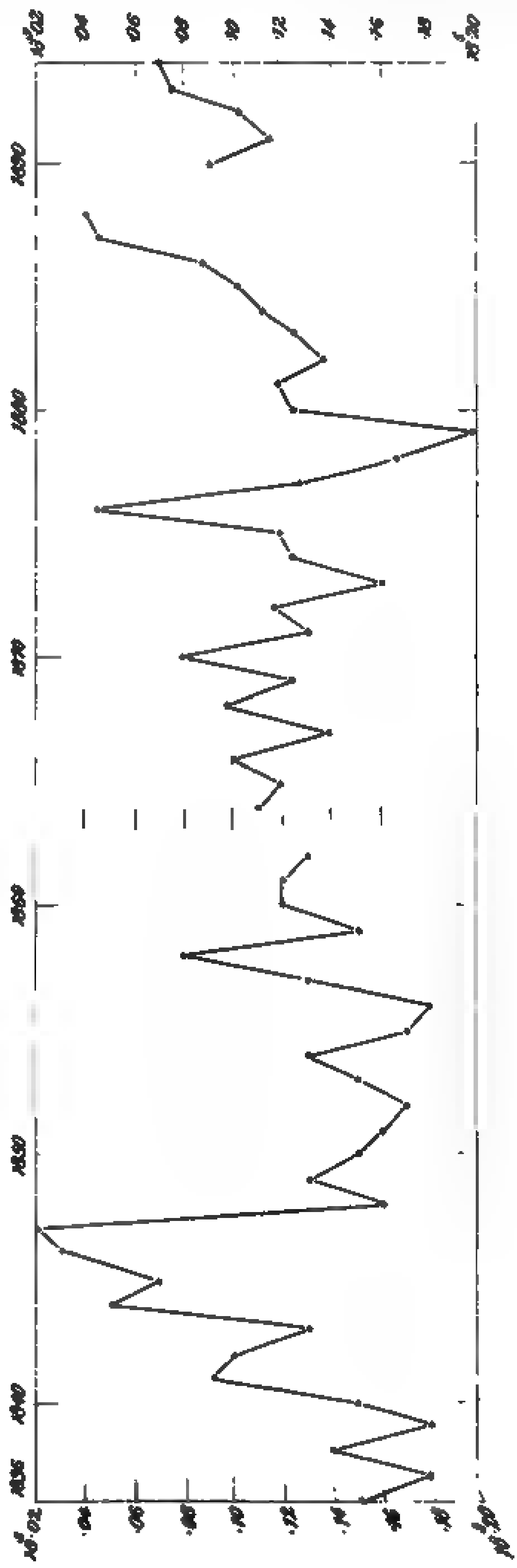
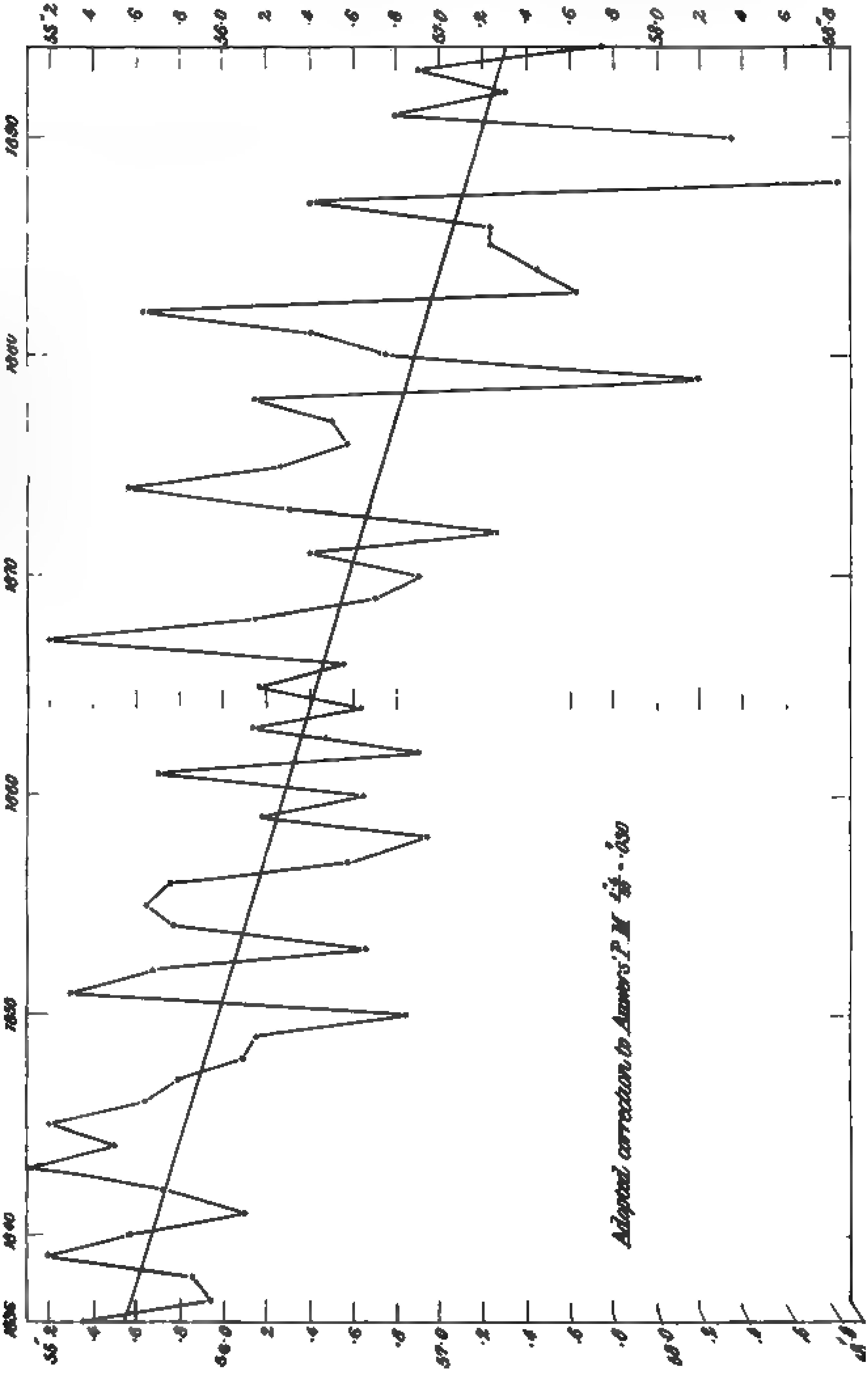


DIAGRAM (3)

[illegible] Distances of Sirius made at the Royal Observatory, Greenwich, 1836–1894 reduced to 1890 with Auwers' correction for linear and orbital motions.



Year and fraction of year.	Mean Right Ascension.			No. of Obs.	Adopted Seconds of R.A. 1890·0.	Year and fraction of year.	Mean North Polar Distance.			No. of Obs.	Adopted Seconds of N.P.D. 1890·0. (a)	(b)
	h	m	s		s		°	′	″		″	″
1863·00	6	39	...	...	...	1863·83	106	31	51·28	1	56·70	57·51
1864·29			9·140	18	·880	1864·28			56·34	15	57·26	58·04
1865·27			11·800	18	17·890	1865·27		32	0·83	18	56·93	57·68
1866·38			14·420	13	17·870	1866·38			4·95	13	57·46	58·18
1867·47			17·100	6	·910	1867·43			9·50	7	56·26	56·95
1868·52			19·710	8	·866	1868·51			12·85	9	57·33	57·99
1869·46			22·380	3	·893	1869·45			18·22	6	58·01	58·64
1870·44			24·980	7	·849	1870·44			23·35	7	58·33	58·93
1871·49			27·730	6	·905	1871·49			27·37	6	57·93	58·50
1872·41			30·310	3	·891	1872·41			33·43	3	58·90	59·44
1873·70			33·005	4	·942	1873·70			38·85	4	58·10	58·61
1874·48			35·615	4	·908	1874·47			41·12	5	57·40	57·88
1875·21			38·258	8	·907	1875·26			46·71	6	58·19	58·64
1876·59			40·836	5	·842	1876·43			51·72	5	58·59	59·01
1877·15			43·560	4	·929	1877·15			57·66	[illegible]	58·57	58·96
1878·51			46·253*	[illegible]	17·979	1878·50		33	2·05*	[illegible]	58·30	58·66
1879·31			48·937	3	18·020	1879·31			8·82	3	60·39	60·72
1880·31			51·516	5	17·955	1880·31			12·08	5	58·98	59·28
1881·19			54·165	2	17·959	1881·19			16·42	2	58·65	58·92
1882·97			56·850	1	18·003	1882·97			(20·29)	1	(57·88)	(58·12)
1883·14			59·486	5	17·993	1883·13			26·99	13	59·88	60·09
1884·11		40	2·130	1	17·993	1884·11			31·47	2	59·68	59·86
1885·35			4·785	4	18·005	1885·47			35·82	3	59·38	59·53
1886·13			7·426	5	18·002	1886·15			40·44	5	59·32	59·44
1887·13			10·050	1	17·981	1887·13			44·16	1	58·28	58·37
1888·04			12·705	2	17·993	1888·04			51·27	2	60·69	60·75
1889			...	...	...	1889			...	...	...	...
1890·12			18·087	3	18·087	1890·09			59·73	2	59·73	59·73
1891·16			20·780	2	·136	1891·16		34	2·47	2	57·76	57·73
1892·71			23·438	4	·150	1892·71			6·99	4	57·55	57·49
1893·21			26·059	14	·127	1893·21			10·98	17	56·85	56·76
1894·42	6	40	28·690	5	·114	1894·42	106	34	15·86	5	57·06	56·94

After applying Professor Auwers' corrections for linear and orbital motions, and giving equal weights to the result of each year's observations, the mean right ascension and north polar dis-

tance of *Sirius* for 1890·0 are $6^h\ 40^m\ 18^s{\cdot}118$ and 106° 33′ 57″·18, and with the corrected proper motion in N.P.D. 106° 33′ 58″·00.

The following table (IV.) gives the mean right ascensions and north polar distances of *Procyon* as taken from the annual catalogues of Greenwich observations reduced to 1890, by the use of Peters' constants of precession, and corrected by Tables I. and II., with Professor Auwers' proper motions of $-0^s{\cdot}0474$ and $+1''{\cdot}027$. The following diagrams exhibit the finally adopted places for 1890, first of all compared with the corrections for orbital motion given by Professor Auwers in *Astr. Nachr.*, Nos. 1371–2–3; and secondly, as corrected by the same quantities.

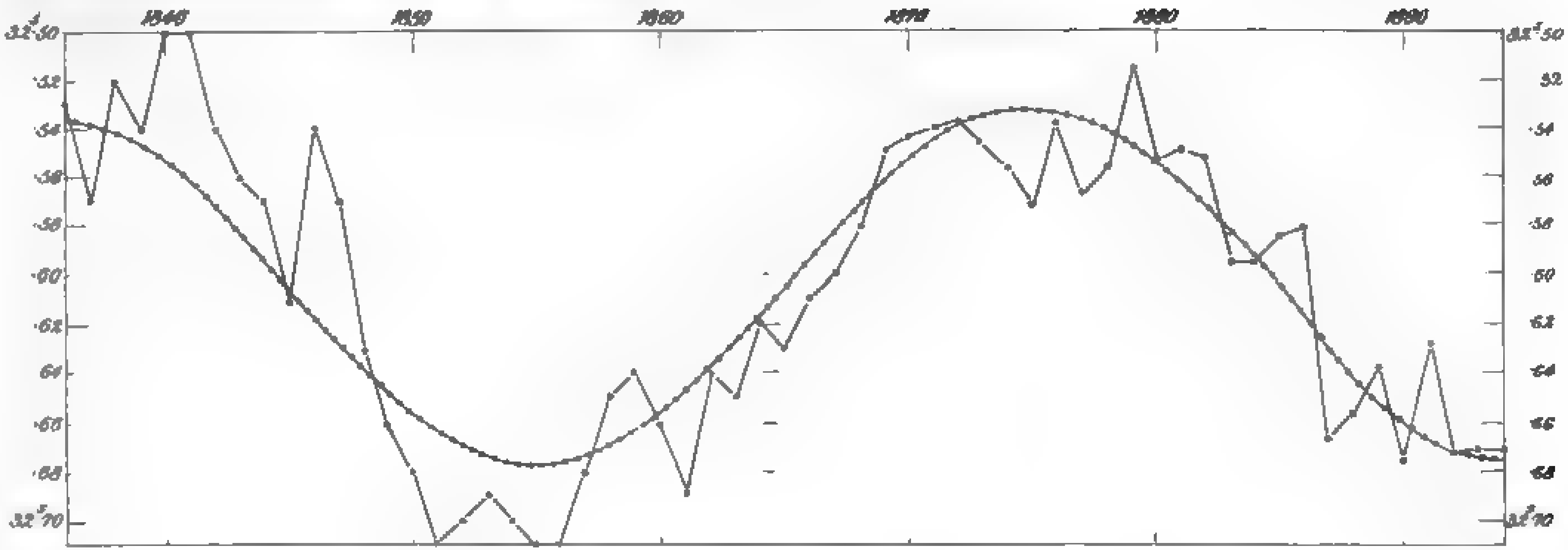
After applying Professor Auwers' corrections for linear and orbital motions, and giving equal weights to the result of each year's observations, the mean right ascension and north polar distance for 1890·0 are $7^h\ 33^m\ 32^s{\cdot}605$ and 84° 29′ 36″·98.

TABLE IV.

Mean Right Ascensions and North Polar Distances of Procyon reduced to 1890·0 *with Peters' constants of Precession and Auwers' proper motion.*

Year and Fraction.	Mean Right Ascension.	No. of Obs.	Adopted Seconds of R.A. 1890.	Year and Fraction.	Mean North Polar Distance.	No. of Obs.	Adopted Seconds of N.P.D. 1890.
	h m s		s		° ′ ″		″
1836·30	7 30 42·770	27	32·530	1836·33	84 21 38·30	12	37·31
1837·38	45·950	27	·570	1837·62	46·20	12	36·46
1838·28	49·060	24	·520	1838·47	55·29	22	36·79
1839·32	52·220	17	·540	1839·43	22 3·60	13	36·59
1840·30	55·350	25	·500	1840·62	11·10	6	35·18
1841·25	58·500	17	·500	1841·29	21·74	8	37·03
1842·40	31 1·680	33	·540	1842·41	28·95	10	35·49
1843·41	4·760	21	·560	1843·38	38·25	9	36·01
1844·41	7·930	25	·570	1844·44	46·94	7	35·91
1845·34	11·090	23	·610	1845·54	55·94	6	36·11
1846·31	14·210	20	·540	1846·23	23 3·88	11	35·24
1847·39	17·370	31	·570	1847·40	14·04	4	36·59
1848·37	20·510	32	·630	1848·23	21·60	13	35·48
1849·31	23·740	25	·660	1849·35	30·33	12	35·44
1850·30	26·910	30	·680	1850·24	39·94	18	36·16
1851·42	30·090	28	·710	1851·41	48·96	24	36·28
1852·28	33·220	44	·700	1852·27	58·14	33	36·56
1853·22	36·360	7	·690	1853·19	24 6·75	1	36·27
1854·31	39·500	28	·700	1854·38	16·23	21	36·96
1855·35	42·650	20	·710	1855·35	25·43	19	37·32
1856·32	7 31 45·800	12	·710	1856·40	84 24 34·15	14	37·19

Right Ascensions of Procyon made at the Royal Observatory, Greenwich 1836-1894 reduced to 1890 with Auwers Proper Motion; compared with Auwers' corrections for orbital motion (Astronomische Nachrichten Nos 1371-2-3.)

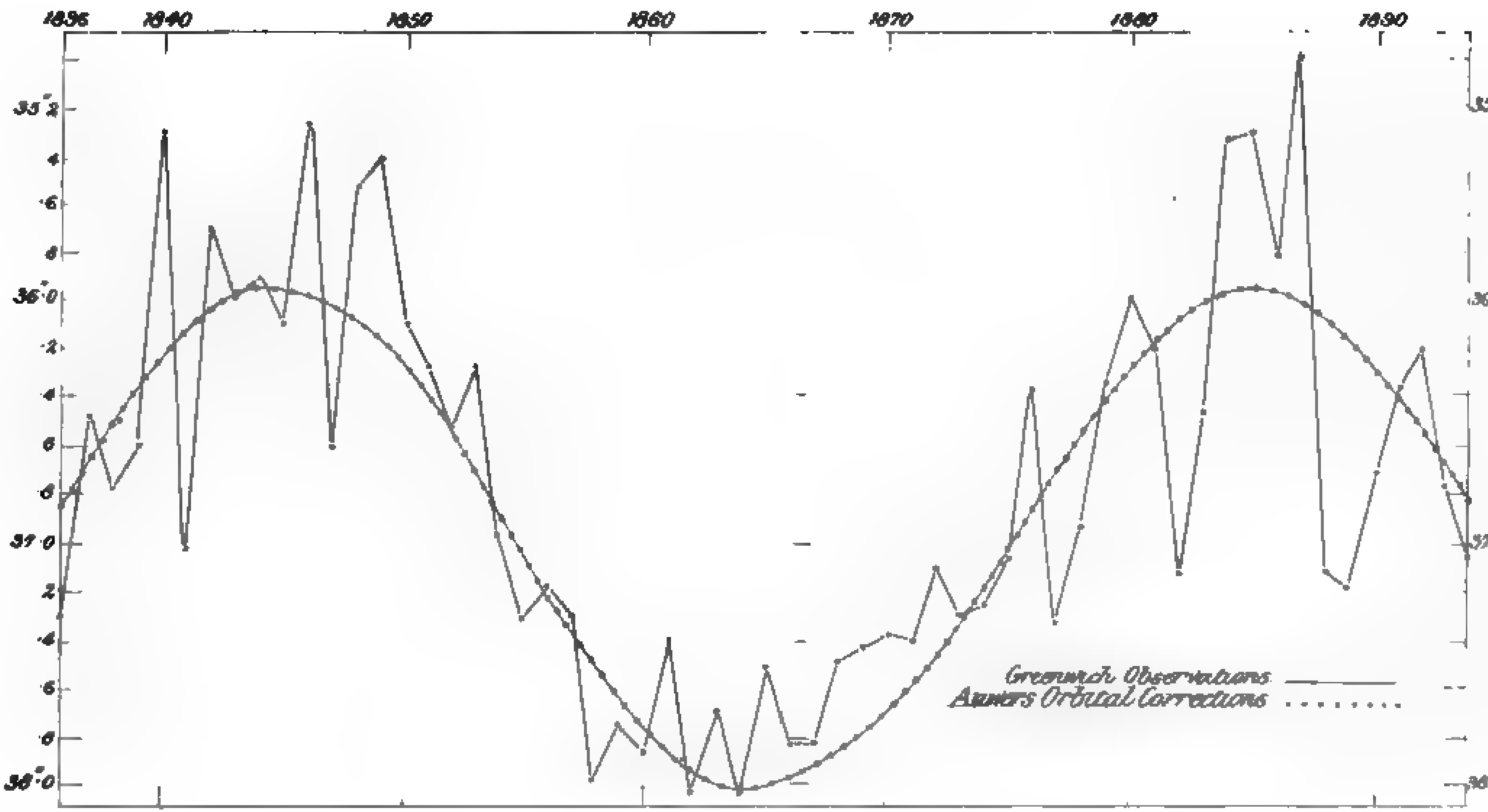


Greenwich Observations ———

Auwers' Corrections -·-·-·-

DIAGRAM (5)

North Polar Distances of Procyon made at the Royal Observatory, Greenwich 1836-1894 reduced to 1890.0 with Auwers' Proper Motion compared with Auwers' corrections for orbital motion Astronomische Nachrichten Nos 1311-2-3



reduced to 1890 with Auwers' corrections for linear and orbital motions.

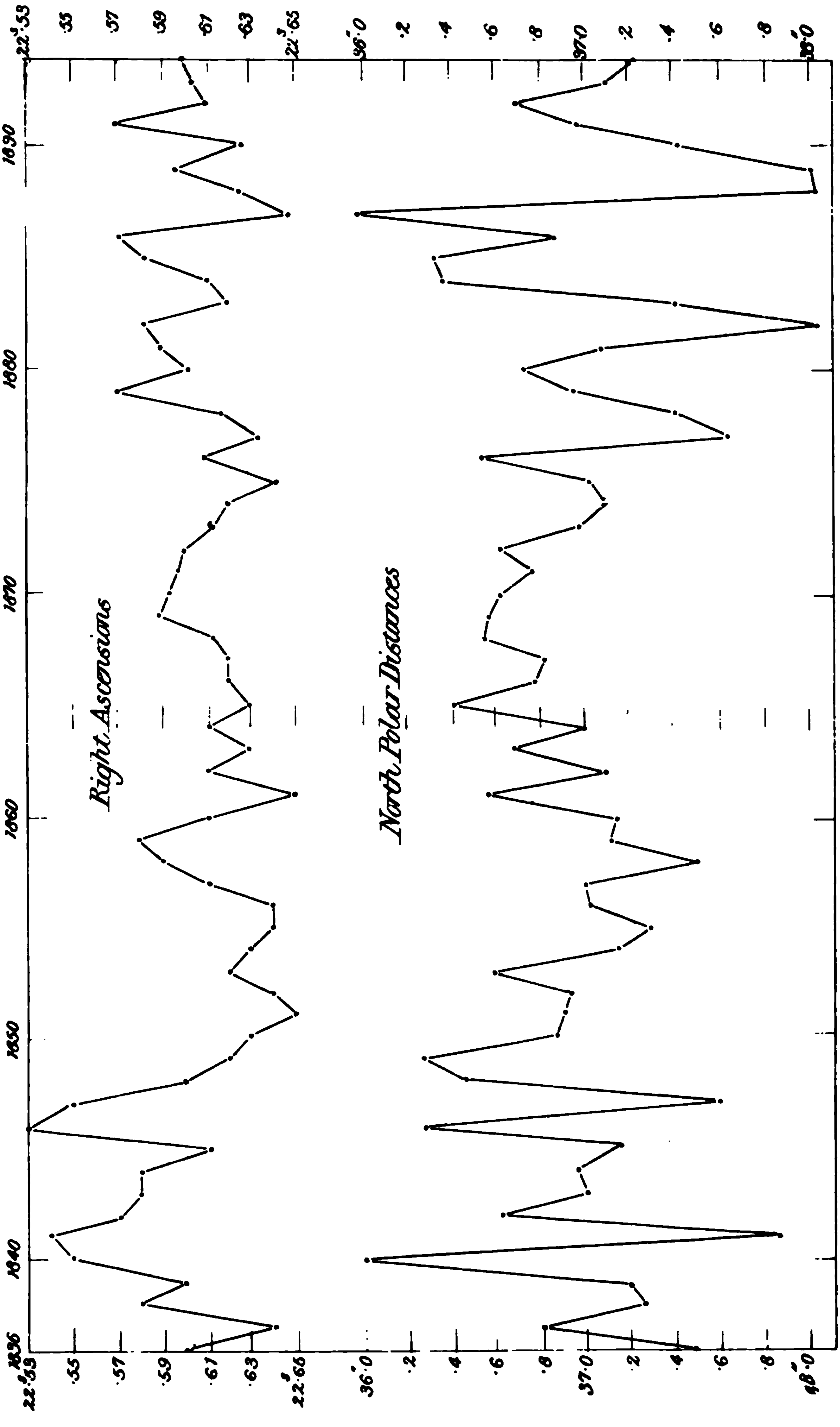


DIAGRAM (7)

Year and Fraction.	Mean Right Ascension.	No. of Obs.	Adopted Seconds of R.A. 1890.	Year and Fraction.	Mean North Polar Distances.	No. of Obs.	Adopted Seconds of N.P.D. 1890
	h m s		s		° ′ ″		″
1857·44	7 31 48·920	22	·680	1857·51	8 24 43·12	16	37·31
1858·41	52·030	17	·650	1858·48	52·65	13	37·99
1859·55	55·170	9	·640	1859·53	25 1·26	9	37·74
1860·37	58·380	10	·660	1860·33	10·27	5	37·86
1861·35	32 1·510	6	·690	1861·51	18·43	4	37·40
1862·67	4·600	5	·640	1862·54	28·06	6	38·05
1863·23	7·760	10	·650	1863·26	36·61	7	37·66
1864·39	10·870	14	·620	1864·42	45·83	12	38·06
1865·39	14·020	20	·630	1865·38	54·16	15	37·46
1866·31	17·150	12	32·610	1866·35	26 3·09	8	37·82
1867·41	20·280	15	·600	1867·49	12·00	9	37·83
1868·45	23·420	16	·582	1868·50	19·93	12	37·49
1869·37	26·530	16	·548	1869·44	28·75	11	37·42
1870·34	29·670	15	·544	1870·42	37·70	13	37·36
1871·39	32·810	23	·541	1871·45	46·57	20	37·39
1872·33	35·950	19	·537	1872·45	55·30	16	37·09
1873·40	39·104	10	·547	1873·44	27 4·38	11	37·30
1874·28	42·255	10	·555	1874·48	13·25	4	37·25
1875·42	45·418	10	·574	1875·53	22·01	12	37·04
1876·55	48·527	14	·539	1876·65	30·24	7	36·36
1877·41	51·697	11	·568	1877·54	40·80	9	37·33
1878·47	54·828	13	·555	1878·48	49·35	13	36·93
1879·34	57·925	6	·513	1879·38	57·72	8	36·35
1880·42	33 1·115	10	·554	1880·42	28 6·31	9	35·99
1881·49	4·254	11	·549	1881·46	15·48	6	36·21
1882·59	7·400	5	·551	1882·64	25·31	1	37·11
1883·50	10·590	6	·597	1883·46	33·63	6	36·47
1884·41	13·735	11	·598	1884·51	41·42	7	35·33
1885·27	16·865	8	·585	1885·33	50·34	6	35·29
1886·55	20·006	7	·582	1886·48	59·81	6	35·83
1887·46	23·238	12	·669	1887·52	29 8·01	8	34·97
1888·54	26·370	4	·657	1888·52	19·13	3	37·10
1889·34	29·493	3	·637	1889·48	28·18	2	37·17
1890·60	32·677	6½	·677	1890·37	36·71	8	36·71
1891·45	35·771	5½	·627	1891·36	45·35	1	36·36
1892·45	38·959	15½	·672	1892·40	54·20	9	36·20
1893·46	42·101	40	·672	1893·46	30 3·73	25	36·77
1894·45	7 33 45·245	23	·671	1894·47	84 30 13·04	25	37·06

For comparison with the last diagrams reference might be made to a paper by Mr. Burnham in the June number of *Astronomy and Astro-physics*, 1894, on the "Variable Proper Motion of *Procyon*," in which he discussed a series of measures of differences in declination between *Procyon* and two adjacent stars made during the years 1851–1890, by Otto Struve, and published in vol. x. of the Pulkova observations.

It does not seem probable that any further discussion of this series of observations, either of *Sirius* or *Procyon*, would lead to any results appreciably different from those deduced by Professor Auwers.

Note on the Measurement of Paper Prints of Stellar Photographs. By Professor H. H. Turner, M.A., B.Sc.

1. The question of the accuracy attainable in measurements of a paper print is important, because the publication of a photograph in this form is a comparatively simple matter. The following brief notes of some experiments recently made at the University Observatory, Oxford, will, perhaps, serve to draw attention to the matter, though they are far from being a complete settlement of the question.

2. It is of course all-important that the original negative should have the *réseau* impressed upon it. If there is no *réseau* on the original negative, a glass copy can be made on which the *réseau* lines have been previously impressed, just as in preparing a plate for the telescope; and the paper prints can then be made from this copy. As a digression I would remark that there are some advantages in *not* having the *réseau* on the original negative. It can be put on the positive copy in the laboratory much more conveniently *and correctly* than on the original negative; that is to say, after examining the negative, and measuring one or two known stars, the *réseau* can be adjusted so that its lines are very nearly in the true directions for epoch 1900·0, and the centre at the proper point on the plate. Further, no stars less than the tenth mag. are obliterated on the original plate. Of course its lines would no longer be parallel to the fiducial edge of the plate. I am supposing this edge to be not used as fiducial.

3. The paper print having then a *réseau* on it, we proceed to measure the position of a star in any square of the *réseau*, for comparison with similar measures on the original negative. The print may be held between two pieces of plate glass, or wetted and squeezed to one of them. It must be viewed by reflected light, not transmitted light, as in the case of the original negative.

4. The following measures in the x coordinate were made of twelve stars on plate 703, and a platinotype print of it.

Plate 703, R.A., 10^h 48^m. zone + 28°, exposed 1895 March 7.

Column 1 gives a number for reference.

Column 2 gives the approximate y coordinate expressed in *réseau* intervals from one corner.

Column 3 gives the diameter of the star-disc on the negative. The letter e denotes that the disc is much elongated, and a mean diameter is given.

Column 4, the x coordinate as measured on the original negative by the glass-scale micrometer described in *Monthly Notices*, lv. p. 102.

Column 5, the x coordinate as measured on the print with the screw micrometer, and the mean of several bisections (the object here being to determine systematic *not* accidental errors). The correction for "runs" was made on the assumption that the deformation was uniform over the square under examination.

Column 6 gives the differences, only one of which is as large as ·003 or 0″·9.

Table I.

(The results are all expressed in *réseau* intervals.)

Star.	y. (Approx.)	Diam.	Coordinate x. Negative.	Print.	P—N.
1	0·3	0·030	8·695	8·696	+·001
2	0·6	·030	9·621	9·621	0
3	0·6	·030	12·082	12·081	− 1
4	1·2	·038e	4·541	4·538	− 3
5	1·5	·012	9·083	9·082	− 1
6	1·8	·010	9·060	9·061	+ 1
7	1·7	·020	20·896	20·897	+ 1
8	1·2	·028	22·533	22·533	0
9	4·2	·023	22·836	22·835	− 1
10	21·2	·017	22·318	22·319	+ 1
11	23·1	·018e	21·741	21·740	− 1
12	20·8	·020	4·632	4·634	+ 2

Measurer of negative, Miss Turner; measurer of print, Mr. Bellamy.

These measures are all near the edge of the plate, where it was expected to find the deformation greatest.

5. The following measures on the same print were made by Professor Turner nearer the middle of the plate, with the glass-scale micrometer in general use for measuring plates. The

measures of the negative in columns (2) and (6) are, as before, those recorded by Miss Turner or Mr. Bennett in the ordinary course of measuring this plate last March. The measures in columns (3) and (7) were repeated specially by Mr. Bellamy. The mean of the two is taken for comparison with those on the print in columns (5) and (9).

TABLE II.

(Results expressed in *réseau* intervals as before.)

Diam. (Negative.)	*x* Coordinate. Negative.		Print.	P—N.	*y* Coordinate. Negative.		Print.	P—N.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8*	4·418	·419	...	...	13·265	·265	...	...
22	5·635	·633	·635	+ ·001	·387	·387	·390	+ ·003
10	9·120	·119	·118	− ·002	·440	·442	·437	− ·004
11	9·702	·703	·698	− ·005	·360	·362	·366	+ ·005
10	9·822	·822	·828	+ ·006	·595	·596	·592	− ·004
13	9·940	·938	·941	+ ·002	·425	·425	·427	+ ·002
8*	10·454	·456	...	...	·507	·507	...	...
20	14·603	·603	·602	− ·001	·378	·377	·380	+ ·002
9	19·589	·589	·589	·000	13·889	·888	·889	·000
10	3·554	·553	·556	+ ·002	14·178	·176	·177	·000
11	7·598	·596	·596	− ·001	·165	·163	·164	·000
12	10·375	·374	·371	− ·004	·314	·312	·312	− ·001
14	21·376	·376	·373	− ·003	14·540	·538	·540	+ ·001

The mean residual is $\pm$·002 or $\pm$ 0″·6. The measures on the print are not so good as those given in Table I. They are single measures with the glass-scale micrometer, instead of means of several careful bisections with a micrometer screw. And some difficulty was found in estimating the place of the broad and diffused images. The *réseau* lines on the plate are in fact not so good as they might be. The plate is, if anything, rather below the average in many respects, and the errors ought not generally to be so large as these.

6. Eleven stars on a pair of platinotype prints were measured with the glass-scale micrometer; the results are given in Table III.

* These two stars were not seen on the print.

TABLE III.

Plate 702. R.A. $10^h\ 30^m$. Zone +28°. Exposed 1895 March 7.

Two Platinotypes (positives) mounted on plate glass, with the back to the glass.

(1) Star.	(2)	(3)	(4)	(5)	(6)	(7)
	x Coordinate.			*y Coordinate*		
	A.	A. (repeated.)	B.	A.	A. (repeated.)	B.
1	11·079	11·085	11·083	2·596	2·587	2·592
2	11·591	11·591	11·595	3·271	3·270	3·281
3	11·723	11·724	11·726	7·210	7·210	7·217
4	11·952	11·951	11·950	9·763	9·762	9·764
5	11·925	11·925	11·925	18·444	18·344	18·339
6	12·378	12·373	12·372	9·874	9·870	9·874
7	12·556	12·556	12·551	11·616	11·618	11·616
8	12·214	12·214	12·215	15·775	15·774	15·776
9	12·589	12·592	12·595	18·627	18·627	18·624
10	12·767	12·771	12·774	20·182	20·182	20·181
11	12·138	12·139	12·140	20·268	20·270	20·267

These measures by Mr. Bellamy.

The measures given in columns (2) and (5) were made on November 6; the light was very bad.

Those in columns (3) and (6) were made on November 7, and are remeasurements of print A.

And those given in columns (4) and (7) were made on November 7, and from a different print, marked B.

The difference in *y* for star 2 is real; Mr. Bellamy went over the measures several times, and also examined all the other large differences.

The *réseau* lines are diffused on both these prints, owing to the lines on the negative being blurred. Another form of micrometer would, therefore, perhaps give better results, especially one where the setting on the *réseau* lines is made by a pair of wires, including a considerable portion of the line.

7. It seems to me, however, that these differences are, on the whole, very small. Briefly we can depend on paper prints (not enlargements, simply contact prints) to give us the places of

stars within $1''$, possibly more accurately, and this is a fact well worth considering. I do not know how far the accuracy of paper prints treated in this way is known. It may be well to recall here some remarks made early in the history of the Chart by Dr. Gill, which perhaps may be taken to represent ideas on the subject generally. Dr. Gill gives no figures, and the only gauge of the accuracy he expects is afforded by the suggestion of a "rule and compass" method; it would appear to me that this does not give a sufficiently high estimate in the light of the above facts.

8. In the Procès-Verbaux of the meeting of the Comité Permanent in 1889 September, Annexe No. 1, are printed the notes presented to the Comité by Dr. Gill, and on p. 85, under the head Publication de la Carte, we read as follows:—

"Des copies de la carte sur verre entraîneraient des dépenses considérables; en outre, ce mode de publication est peu commode si l'on veut mesurer les plaques à l'aide d'une lunette, les images stellaires sur le négatif original étant trop petites pour être aperçues à l'œil nu. Le mode le plus simple consisterait, je le crois, à reproduire les plaques originales sur du papier, à l'aide de la photogravure ou de tout autre procédé analogue, en les agrandissant de trois diamètres, afin de rendre visibles les étoiles les plus faibles. . . . A l'aide du compas et de la règle on pourra déterminer sur ces copies à l'échelle de $3^{mm} = 1'$ la position d'une étoile quelconque du cliché, sinon avec une extrême, du moins avec une grande précision. Ce mode de publication ne serait pas très coûteux, la dimension des plaques serait peu gênante; de plus, on pourrait éliminer toute déformation du papier en ayant égard aux lignes du *réseau.*"

9. The deformation of the paper has of course been allowed for in the above measures by the method of "runs," assuming it uniform throughout a square. It is a sensible quantity, and (as might be expected) different in the two coordinates. The stretching in the case of the above platinotype print was about ·003 in one direction and about ·013 in the other—a difference of 1 per cent. To test the regularity of the stretching across the paper, the widths of the spaces between consecutive *réseau* lines were measured across the plate, as below (Table IV.) with the screw micrometer. The results are expressed in *réseau* intervals as usual. The screw is not quite uniform, but the same part of it was used in measuring negative and print, so that the irregularity is eliminated from the differences N – P. The measures were made by Mr. Bellamy.

TABLE IV.

(1) Space.	(2) Interval on Negative.	(3) Interval on Print (1).	(4) Interval on Print (2).	(5) N−P₁.	(6) N−P₂.
0–1	0·9990	0·9961	...	+·0029	...
1–2	1·0007	0·9947	...	+·0060	...
2–3	0·9993	0·9974	...	+·0019	...
3–4	1·0004	0·9973	...	+·0031	...
4–5	1·0015	0·9984	...	+·0031	...
5–6	0·9981	0·9938	...	+·0043	...
6–7	1·0010	0·9986	...	+·0024	..
7–8	1·0012	0·9968	...	+·0044	...
8–9	0·9995	0·9953	...	+·0042	...
9–10	1·0010	0·9981	0·9960	+·0029	+·0040
10–11	0·9999	0·9966	0·9991	+·0033	+·0008
11–12	1·0000	0·9930	0·9902	+·0070	+·0098
12–13	1·0003	0·9989	0·9989	+·0014	+·0014
13–14	1·0015	0·9998	0·9981	+·0017	+·0034
14–15	1·0000	0·9936	0·9950	+·0064	+·0050
15–16	1·0003	0·9966	0·9977	+·0037	+·0026
16–17	1·0007	1·0020	1·0016	−·0013	−·0009
17–18	1·0007	0·9956	0·9970	+·0051	+·0037
18–19	1·0016	0·9970	...	+·0046	...
19–20	1·0005	0·9984	...	+·0021	...
20–21	0·9988	0·9943	...	+·0045	...
21–22	1·0006	0·9992	...	+·0014	...
22–23	1·0018	0·9977	...	+·0041	...
23–24	1·0008	0·9951	...	+·0057	...
24–25	1·0006	0·9930	...	+·0076	...
25–26	1·0023	0·9984	...	+·0039	...

The differences shown in column (5) are fairly regular with a few exceptions. To test the reality of the exceptions, the portion 9–18 was remeasured, as shown in columns (4) and (6). The differences in column (6) agree sufficiently well with those in column (5) to show that the abnormality of space 16–17, for instance, is real; but at the same time there are undoubtedly sensible accidental errors. Cp. the measures of space 10–11.

The existence of three consecutive spaces like 15–16, 16–17, and 17–18, whose widths are in the proportion 0·997, 1·001, 0·996, shows that the assumption of uniformity in the "runs" throughout one interval will not always give us accurate results, for we have no information as to where the change takes place.

10. The present note is not concerned with several matters of great importance; as, for instance, the possibility of securing all the stars on the print which are on the original plate. In the print above measured faint stars have certainly been lost. For the present I am only concerned with the value of such prints, in default of the original plate, for getting star-places with considerable accuracy. The experiments will be continued, and a fuller account of them given later. But if the question of the publication of the Chart is to be dealt with at the next meeting of the Permanent Committee, it is not too early to draw attention to the possibilities contained in paper prints, which have so many advantages over glass copies in the way of convenience.

Photograph of the Nebula ♅ *VI.* 41 *and a new Nebula in Draco.* By Isaac Roberts, D.Sc., F.R.S.

The photograph of the spiral nebula ♅ VI. 41 *Draconis*, R.A. $17^h\ 33^m$, Decl. $75°\ 48'$ north, and of the new elliptic nebula, R.A. $17^h\ 26^m\ 21^s$, Decl. $75°\ 8'{\cdot}6$ north (epoch 1860), was taken with the 20-inch reflector on 1895 September 11, with an exposure of the plate during 60 minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 15 seconds of arc.

The nebula ♅ VI. 41 is N.G.C. No. 6412, G.C. No. 4321, and is described by Sir J. Herschel as a globular cluster, considerably large, round, very gradually brighter in the middle, partially resolved.

The photograph shows it to be a spiral nebula, with a bright stellar nucleus, which appears to be elongated in *north following* and *south preceding* directions; and, involved in the spirals, are three or four nebulous star-like condensations. The general appearance of the nebula, and of the surrounding region of the sky, will best be appreciated on the photo-copy of the negative, now projected on the screen.

The elliptic nebula (supposed to be here recorded for the first time) is elongated in nearly *north* and *south* directions, with dense nebulous condensations in the interior and well-defined margins on the *preceding* and *following* sides, but the north and south ends are undefined, and shade gradually into invisibility. The length of the nebula does not exceed 70 seconds of arc, and the 9·2 magnitude star, D.M. No. 629, zone 75°, is about 30 seconds of arc *south preceding* it.

It will be observed on the photograph that the region of the sky surrounding these nebulæ is rather sparingly covered with stars, and that they are all fainter than 8th magnitude.

Photograph of the Cluster H VIII. 76 *and of a new Nebula in Cygnus.* By Isaac Roberts, D.Sc., F.R.S..

The photograph of the cluster H VIII. 76 R.A., $20^h\ 51^m\cdot5$, Decl. 46° 53′ north, and of a new nebula in *Cygnus* was taken with the 20-inch reflector on 1895 September 13, with an exposure of the plate during two hours. The copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The cluster is N.G.C. No. 6991, G.C. No. 4615, *h* 2091, and is described by Sir J. Herschel as large, poor, very little compressed.

The photograph shows that there is no cluster, in the ordinary, accepted use of the word, on the plate, but that there are densely crowded areas of stars in this as well as in many other regions of the sky; and I may here remark that Herschel's 8th class of clusters would be better designated as rich fields of stars. This designation, again, could be only relative, for an increase in the magnifying power of the observing instrument or of the photo-camera would separate the stars so that our ideas of a relationship between them would be entirely changed.

The new nebula (supposed to be here recorded for the first time) is in R.A. $20^h\ 50^m\ 56^s$, Decl. 46° 51′·9 north (epoch 1855), and it either involves, or else just touches, the star D.M. No. 3111 zone + 46°. It is about 6½ minutes of arc in length from north to south, and 5 minutes of arc in breadth from *preceding* to *following*, irregular in outline and with many stars, both bright and faint, involved or in alignment with it. The nebulosity has no regular structure and is of a fleecy character, the margins gradually fading into invisibility.

The photograph shows that this nebula is surrounded by stars more numerous than is generally the case in the regions contiguous to nebulæ.

The Orbit of Σ 1879. By T. Lewis.

Observations of this binary are very scarce, although it has been known since 1827, when it was measured by W. Struve. This summer I had an opportunity of examining it with the 28-inch Greenwich refractor, and have deduced a provisional orbit principally to call attention to it. The position for 1900 is

R.A. $14^h\ 41^m\ 20^s$ N.P.D. 79° 55′ Mags. 7·7 and 8·5.

The residuals are in some cases large but are well within the discordances of the observations. The difficulty of the object since 1850 is sufficient to account for these variations, indeed the

law of equal areas is better satisfied than I had expected. The comparison of the apparent ellipse with observed places gives the best general idea.

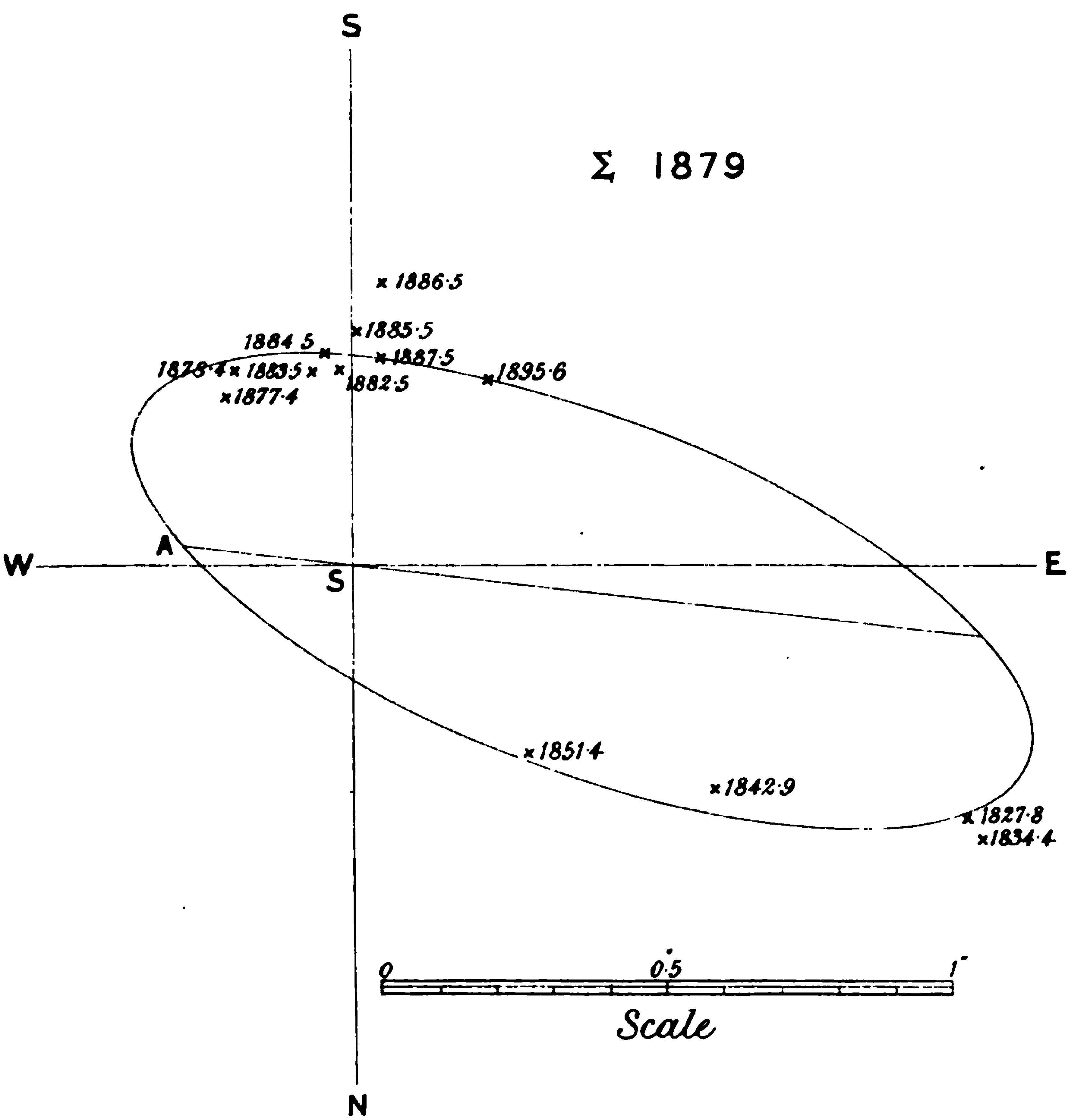
The elements are

τ	1865·0	☊	64° 1′
p	146·9 years	γ	67 48
ϵ	·581	λ	222 47
a	0″·92	μ	−2°·45

Below is a comparison with all the observations I have been able to find, and a short ephemeris.

Date.	Position angle Observed.	Position angle Calculated.	Distance Observed.	Distance Calculated.	Observer.
1827·27	69°·7	67°·9	1″·12	1″·15	W. Struve
1828·32	65·8	67·3	1·22	1·13	W. Struve
1834·39	66·3	64·3	1·21	1·03	W. Struve
1842·42	59·2	59·0	0·80	0·85	Mädler
1843·42	57·2	58·2	0·69	0·82	Mädler
1851·41	43·5	47·9	0·45	0·55	Mädler
1877·40	30· ±	218·0	0·42	0·43	Burnham
1877·44	219·1	218·0	0·37	0·43	Schiaparelli
1877·46	222·9	217·9	0·34	0·43	Dembowski
1878·39	206·6	214·7	0·39	0·43	Dembowski
1878·44	217·1	214·6	0·42	0·43	Burnham
1882·50	183·5	198·9	0·35	0·39	Schiaparelli
1883·47	177·9	194·0	0·38	0·39	Schiaparelli
1883·55	209·4	193·9	0·31	0·39	Engelmann
1884·50	187·3	190·0	0·37	0·38	Schiaparelli
1885·48	179·5	185·4	0·41	0·37	Schiaparelli
1886·51	174·2	180·8	0·50	0·37	Schiaparelli
1887·44	173·1	175·8	0·38	0·37	Hall
1887·49	173·1	175·7	0·35	0·37	Schiaparelli
1895·44	144·6	140·5	0·40	0·41	Lewis
...	...	...	...	...	
1896·5	...	137·0	...	0·43	
1897·5	...	133·6	...	0·45	
1898·5	...	130·3	...	0·47	
1899·5	...	127·2	...	0·48	
1900·5	...	124·6	...	0·50	

1895 *November* 4.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Observations of the Variable Star T Centauri.
By Lieut.-Col. E. E. Markwick.

This star proves to be an interesting variable on account of the large range in variation, 4½ magnitudes, and its comparatively short period. My observations, in continuation of those on p. 247, vol. v. *Journal B. A. Assoc.*, are as follows. They were usually made with a binocular magnifying five times, supplemented by a 2¾-inch refractor, power 28. The comparison star, for the brighter stages, was L 5649, which is 23′ S of the var., and rated $7^m{\cdot}0$ in the *Uranometria Argentina*. The difference in brightness was estimated in steps, or tenths of a magnitude.

1894.	m		m		m		m
Dec. 29	7·1	May 14	8·0	June 3	6·0	June 23	6·5
1895. Jan. 2	7·2	15	7·4	4	6·0	24	6·6
6	7·5	16	7·4	5	5 to 5½	26	6·65
29	9	17	7·3	6	5·5	27	6·7
Apr. 19	9·25	19	7·3	8	5·3	29	6·8
20	9·6	20	7·25	10	5·5	30	6·7
21	9·75	21	7·2	11	6·25	July 1	6·8
22	9·75	22	7·2	12	6·2	2	6·8
25	10	25	7·05	13	6·3	3	6·8
26	10	26	7·0	14	6·2	8	7·1
May 3	9·7	28	6·8	16	6·0	11	7·5
5	9·6	30	6·25	17	6·25	12	7·75
6	9·3	31	6·25	19	6·27	13	7·75
7	9·22	June 1	6·25	20	6·3	14	7·75
8	8*	2	6·0	21	6·4	17	8·5
						21	9·5

I attach a drawing showing the light-curve in 1894 and 1895 as deduced from the previous and the 1894 observations.

Neither of these, it will be observed, gives a complete cycle of variation, and it is somewhat difficult to arrive at the period. In the above-quoted paper seventy-three days was thought to be something near the truth, and from the additional observations now obtained it would appear that this is so.

The star was observed $6^m{\cdot}25$ on 1894 May 26, but there was a gap in the observations of seventeen days prior to this, the next preceding observation being 8^m on May 9. Now an in-

* Very bright moonlight, making observation difficult.

spection of the 1895 curve shows the maximum to have occurred eight days prior to the secondary maximum indicated by the "hump" on the curve for June 16. Accordingly, taking eight days from 1894 June 2, the date of the secondary maximum or that year, we get 1894 May 25 as a fairly probable date of maximum. This is corroborated by the photographic magnitudes of the star communicated by Professor E. C. Pickering to *Astr. Nachr.* No. 3269, col. 72, which show it to be actually slightly rising on 1894 May 24. The last plate taken on that day shows it as brighter than on any other occasion, although twenty-three plates were taken on various dates in the years 1889–1894.

The maximum in 1895 may pretty safely be allocated from my observations to June 8.

From 1894 May 25 to 1895 June 8 is 379 days. Supposing five periods to have elapsed in the interim, we get (i) 75·8 days as mean period.

From the photographic magnitudes the star appears to have been at or near a minimum on 1893 July 27. My observations show a minimum pretty clearly on 1895 April 26. From the former to the latter is 638 days. Taking nine periods to have elapsed, this gives (ii) 70·9 days as mean period.

We now get from the mean of (i) and (ii) as approximate elements of maximum, epoch 1894 May 25 (Julian, 241, 2974) + 73·35 *d*.E. Variation, maximum 5·3 – 6·25 to minimum 10·0. Interval from minimum to next succeeding maximum forty-three days.

This will suit the observations of December 1894 and January 1895, supposing a faint maximum to have occurred about them.

With the above elements the photographic magnitudes of Pickering have been compared by plotting them on a typical light-curve. Those of 1894 agree fairly well. Those of 1893 do not, as they would appear to show the star's light to be falling when calculation makes it rising. In 1892 only one plate was taken. In 1891 and 1889 it is impossible to deduce any regular change. In 1890 the slight variation shown is fairly in agreement.

On the whole, seeing the short time the star has been under observation since its discovery, I can only regard these elements as provisional.

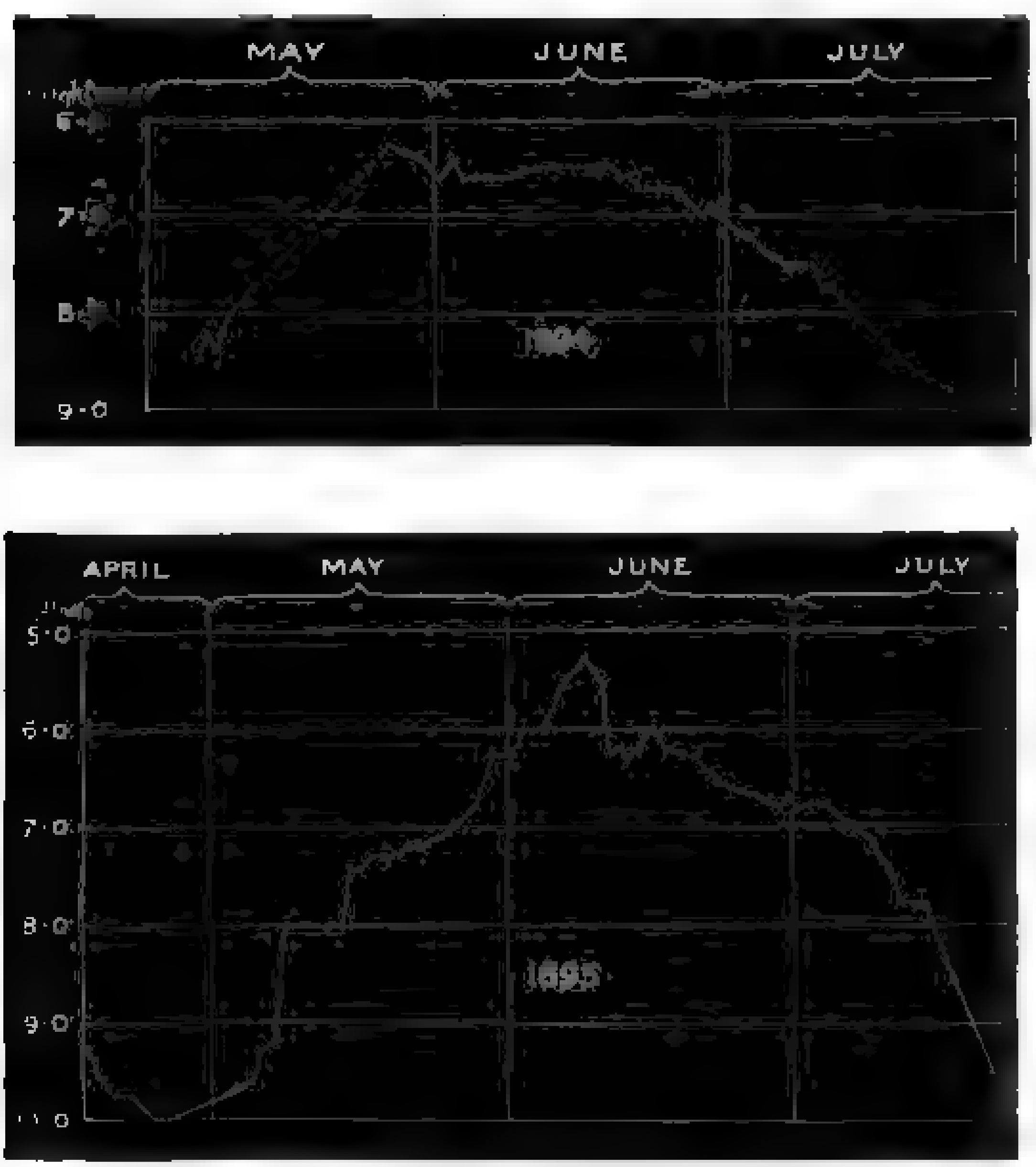
As noted in my paper in the *B. A. A. Journal*, it was observed by Lacaille (7^m) between June 16 and June 26, 1752. Say (*a*) June 21 as mean. It is No. 5738 of Yarnall, and rated $6^m \cdot 0$. Observed at Washington in R.A. (*b*), 1862·80, and in declination (*c*), 1870·40. Supposing the star was at maximum on these three occasions, we have from

a to *b*	= 40,296 days
b to *c*	= 2.776 „
b to 1894 May 25	= 11.541 „

With a period of 73·35 days, the residuals are respectively 27 days, 11 days, and 25 days.

However, it is quite possible that there may be inequalities in the period which would throw out the maximum considerably when calculated for a lengthy period of years. Again, the star evidently varies very slowly about the time of maximum, so that the three ancient dates mentioned are merely approximate, so far as they are regarded as representing the maximum. These observations may therefore possibly be in accordance with the period named, supposing there are inequalities in it.

It is probable the brightness varies at different maxmia.



Light variations of *T Centauri.*

In the latitude of Gibraltar one can only observe it in ordinary working evening hours for a comparatively short time each year. A regular series of observations made in the southern hemisphere over a year or two would very soon throw much light

on the variation, and it is much to be desired that someone in the Cape or Australia will take it up.

The position of the star for 1906 is R.A. $13^h\ 36^m\ 2^s$, Decl. $-33°\ 5'.5$; No. 4896 in Chandler's List of New Variables supplementary to Cat. in No. 300 of the *Ast. Journal*. It is also No. 252 of *Centaurus* in the *Uran. Arg.*

On 1895 May 14 it was slightly orange in tint; May 15, in 2¾-inch refractor, various powers, 28 to 200, noted as slightly yellow. Generally speaking, towards maximum it appears yellowish with tinge of orange; and after maximum I think the orange tint is slightly more pronounced.

It may possibly be of the type of *S Vulpeculæ* or *R Sagittæ*, although the range of variation is greater.

Gibraltar: 1895 October.

Results of Filar Micrometer Comparisons of Saturn with 96 Virginis, and of Ceres with Neighbouring Stars. By John Tebbutt.

The accompanying table contains the results of comparisons with the filar-micrometer on the 8-inch equatorial. In the comparisons of *Saturn* the first and north, and second and south, limbs were observed alternately, and the differences of R.A. and N.P.D. for both planets have been corrected for refraction, and a small error in the perpendicularity of the micrometer threads. The semidiameter of *Saturn* and the parallaxes of both planets have been taken from the *Nautical Almanac*, and the resulting geocentric places have finally been compared with the ephemerides on page 262 of the almanac and page 4 of its appendix. The errors for *Saturn* differ but little from those determined by me in May last from comparisons with *κ Virginis* and already forwarded to the Society.

Saturn.

Date.	Windsor Mean Time.	Planet's Centre – Star. R.A.	Planet's Centre – Star. N.P.D.	No. of Comps.	Star Reductions R.A.	Star Reductions N.P.D.	Parallax Corrections. R.A.	Parallax Corrections. N.P.D.	Geocentric Apparent Place of Planet's Centre. R.A.	Geocentric Apparent Place of Planet's Centre. N.P.D.	Comp. Star.	Error of *Nautical Almanac* R.A.	Error of *Nautical Almanac* N.P.D.
1895.	h m s	m s	′ ″		s	″	s	′	h m s	° ′ ″		s	″
Aug. 4	7 10 28	−3 22.65	− 7 51.8	20	+1.96	+14.6	+0.03	+0.4	14 0 4.22	99 42 36.2	1	+0.14	+1.7
8	8 3 53	−2 35.72	− 2 33.3	11	+1.92	+14.4	+0.04	+0.4	14 0 51.12	99 47 54.5	1	+0.14	+1.9
9	7 33 39	−2 23.47	− 1 12.4	20	+1.91	+14.4	+0.03	+0.4	14 1 3.35	99 49 15.4	1	+0.09	+2.2
10	7 42 14	−2 10.69	+ 0 13.0	20	+1.90	+14.3	+0.04	+0.4	14 1 16.13	99 50 40.7	1	+0.14	+2.0
11	7 22 19	−1 57.75	+ 1 38.1	20	+1.88	+14.2	+0.03	+0.4	14 1 29.04	99 52 5.7	1	+0.14	+2.0
12	7 32 53	−1 44.28	+ 3 7.4	18	+1.87	+14.2	+0.03	+0.4	14 1 42.50	99 53 35.0	1	+0.18	+1.0

Ceres.

Date.	Windsor Mean Time.	Planet's Centre – Star. R.A.	Planet's Centre – Star. N.P.D.	No. of Comps.	Star Reductions R.A.	Star Reductions N.P.D.	Parallax Corrections. R.A.	Parallax Corrections. N.P.D.	Geocentric Apparent Place of Planet's Centre. R.A.	Geocentric Apparent Place of Planet's Centre. N.P.D.	Comp. Star.	Error of *Nautical Almanac* R.A.	Error of *Nautical Almanac* N.P.D.
June 28	10 6 30	+1 16.07	− 4 44.9	10	+3.71	+ 7.3	−0.13	+0.7	18 15 5.27	117 22 26.1	2	−1.80	−5.8
29	8 41 47	+0 20.96	− 1 28.5	6	+3.72	+ 7.3	−0.22	+1.1	18 14 10.08	117 25 42.9	2	−1.91	−6.5
30	9 39 14	−0 40.23	+ 2 4.9	10	+3.73	+ 7.3	−0.15	+0.7	18 13 8.97	117 29 15.9	2	−1.66	−7.0
30	9 39 14	−0 2.08	...	10	+3.74	...	−0.15	...	18 13 8.95	...	3	−1.64	...
July 1	8 44 55	−1 36.03	+ 5 17.4	10	+3.75	+ 7.4	−0.20	+1.0	18 12 13.14	117 32 28.8	2	−1.88	−7.3
1	8 44 55	−0 57.97	...	10	+3.75	...	−0.20	...	18 12 13.02	...	3	−1.76	...
2	8 21 28	−2 33.07	+ 8 30.6	8	+3.76	+ 7.4	−0.22	+1.1	18 11 16.09	117 35 42.1	2	−1.79	−7.7
2	8 21 28	−1 54.88	...	8	+3.76	...	−0.22	...	18 11 16.10	...	3	−1.80	...
4	8 51 22	−1 4.51	− 2 55.3	9	+3.78	+ 7.7	−0.18	+0.8	18 9 20.22	117 42 2.6	4	−1.62	−5.0
5	9 6 46	−2 1.41	+ 0 10.0	9	+3.79	+ 7.8	−0.16	+0.7	18 8 23.35	117 45 7.9	4	−1.84	−5.2
7	8 12 36	−1 23.55	−12 24.5	9	+3.81	+ 8.3	−0.20	+1.0	18 6 34.27	117 50 53.4	5	−1.83	−4.0
8	8 45 56	+0 27.88	− 9 30.3	10	+3.82	+ 8.4	−0.16	+0.8	18 5 38.65	117 53 47.5	5	−2.03	−4.0

Date.	Windsor Mean Time.	Planet's Centre—Star. R.A.	Planet's Centre—Star. N.P.D.	No. of Comps.	Star Reductions R.A.	Star Reductions N.P.D.	Parallax Corrections. R.A.	Parallax Corrections. N.P.D.	Geocentric Apparent Place of Planet's Centre. R.A.	Geocentric Apparent Place of Planet's Centre. N.P.D.	Comp. Star.	Error of *Nautical Almanac.* R.A.	Error of *Nautical Almanac.* N.P.D.
1895.	h m s	m s	′ ″		s	″	s	″	h m s	° ′ ″		s	″
July 9	8 49 41	−0 26·37	− 6 44·7	10	+3·82	+ 8·4	−0·16	+0·7	18 4 44·40	117 56 33·0	5	−1·71	−3·3
12	7 38 8	−3 0·08	+ 0 59·7	10	+3·84	+ 8·5	−0·21	+1·0	18 2 10·66	118 4 17·8	5	−1·74	−4·6
15	7 17 2	−0 27·39	−11 1·6	10	+3·85	+ 9·1	−0·21	+1·0	17 59 43·60	118 11 28·5	6	−1·79	−4·0
15	7 17 2	−1 46·08	...	10	+3·86	...	−0·21	...	17 59 43·51	...	7	−1·70	...
16	8 3 16	−1 16·06	− 8 39·1	10	+3·85	+ 9·2	−0·17	+0·7	17 58 54·97	118 13 50·8	6	−1·80	−5·8
16	8 3 16	−2 34·66	...	10	+3·86	...	−0·17	...	17 58 54·97	...	7	−1·80	...
17	8 32 4	−2 3·03	− 6 24·8	10	+3·85	+ 9·2	−0·13	+0·6	17 58 8·04	118 16 5·0	6	−1·74	−5·3
17	8 32 4	−3 21·65	...	10	+3·86	...	−0·13	...	17 58 8·02	...	7	−1·72	...

Adopted Mean Places of the Comparison Stars for 1895·0.

Star.	R.A.	N.P.D.	Authorities.
	h m s	° ′ ″	
1	14 3 24·88	99 50 13·0	Greenwich Catalogues for 1864, 1872, 1880, and Radcliffe Catalogues for 1860, 1890.
2	18 13 45·62	117 27 3·0	Arg. Oeltzen 18,047, Arg. Gen. Cat. 24,978.
3	18 13 7·44	117 32 52·6	Arg. Oeltzen 18,028.
4	18 10 21·13	117 44 49·4	Arg. Gen. Cat. 24,884, Stone 9,960.
5	18 5 7·11	118 3 8·6	Arg. Oeltzen 17,772, Arg. Gen. Cat. 24,748.
6	18 0 7·35	118 22 20·0	Arg. Oeltzen 17,611, Arg. Gen. Cat. 24,623, Stone 9,860.
7	18 1 25·94	118 28 5·0	Arg. Oeltzen 17,653, Arg. Gen. Cat. 24,649, Stone 9,869.

Private Observatory, Windsor, N.S. Wales:
1895 *September* 13.

Observations of Encke's Comet made with the 15-inch Equatorial of the National Mexican Observatory, Tacubaya. By Felipe Valle.

(Communicated by the Secretaries.)

Long. W. $6^h\ 36^m\ 46^s.53$. Lat. N. $19^\circ\ 24'\ 17''.5$.

Date.	Tacubaya Mean Time.	Comet—Star. Δα	Δδ	No. of Comps.	Observer.	Comet App. R.A.	Log. $p\times\Delta$ of Parallactic Factor.	Comet App. decl.	Log. $p\times\Delta$ of Parallactic Factor.	Red. to App. Place.		No. of Star.
	h m s	m s	′ ″			h m s		° ′ ″		s	″	
1894. Dec. 28	7 40 28·6	+3 48·13	+0 01·32	6–6	F. V.	22 14 49·03	+9·6790	+3 20 29·9	+0·4236	+2·31	+14·29	1
29	7 34 18·7	−0 33·17	+3 07·08	10–10	„	22 14 33·68	+9·6767	+3 22 08·8	+0·4246	+2·35	+14·75	2
31	7 39 52·9	+0 42·76	−1 27·90	9–9	„	22 14 01·59	+9·6918	+3 06 17·4	+0·4329	+2·31	+14·12	3
1895. Jan. 4	7 31 55·0	+0 54·48	−0 45·50	12–12	„	22 12 27·64	+9·7005	+2 29 56·9	+0·4410	−0·75	− 5·75	4
12	7 10 34·9	−1 18·65	−0 05·36	7–7	„	22 06 03·61	+9·7138	+0 39 55·3	+0·4601	−0·78	− 5·66	5
14	7 25 16·9	−0 13·95	+0 55·01	4–4	„	22 03 09·83	+9·7299	−0 02 08·2	+0·4658	−0·79	− 6·12	6
15	7 03 07·2	−1 43·26	+2 22·11	7–7	„	22 01 33·63	+9·7201	−0 24 52·4	+0·4686	−0·78	− 6·29	7
17	6 53 15·7	−1 33·01	+1 25·48	7–7	„	21 57 32·85	+9·7205	−1 19 14·0	+0·4746	−0·79	− 6·76	8
18	7 11 35·7	+1 11·63	+1 53·22	4–4	„	21 55 08·29	+9·7359	−1 51 11·8	+0·4710	−0·80	− 7·10	9
19	6 53 43·4	−0 22·79	−5 34·74	11–11	„	21 52 30·52	+9·7297	−2 25 16·0	+0·4789	−0·80	− 7·27	10
21	6 51 36·0	−0 37·75	−5 21·52	8–8	„	21 46 15·25	+9·7358	−3 45 28·9	+0·4465	−0·78	− 7·81	11
22	6 45 29·4	−4 38·20	−2 01·26	1–1	„	21 42 37·38	+9·7370	−4 31 17·1	+0·4843	−0·79	− 7·98	12

Comparison Stars

No. of Star.	α 1894·0–1895·0 h m s	δ 1894·0–1895·0 ° ′ ″	Authority.	Date. 1894.	Observed Δα. s	Calculated Δδ. ″	Ephemerides.
1	22 10 58·59	+3 30 14·3	Schjellerup ½ (9096+9097)	Dec. 28	+1·48	−0·1	Backlund, Bull. Acad. St. Pétersbourg, I.
2	(2a −4 00·63)	(2a+2 25·21)	Anon. Ref. to 2a (10·0)	29	...	...	"
2a	22 19 05·13	+3 16 22·0	B. D. +3°·4701 (8·5)				
3	22 13 16·52	+3 07 31·3	B. D. +2°·4490 (9·0)	31	...	...	"
4	22 11 33·91	+2 30 48·1	(9·0) B. D. +2°·4485	1895. Jan. 4	+1·33	+2·17	"
5	22 07 23·04	+0 40 06·3	(8·3) B. D. +2°·4836	12	...	...	"
6	22 03 24·57	−0 02 57·1	(9·3) B. D. +0°·4313	14	...	...	"
7	22 03 17·67	−0 27 08·2	(8·5) 9033 Schjellerup	15	+5·37	+31·1	"
8	(8a − 16·68)	(8a+4 17·64)	B. D. −1°·4242. Ref. to 8a	...	...	...	"
8a	21 59 23·33	−1 24 50·4	(6·5) 5936 Radcliffe 1890	17	+6·84	+52·2	"
9	21 53 57·46	−1 52 57·9	(8·9) 5919 Radcliffe 1890	18	+6·86	+45·5	"
10	21 52 54·11	−2 19 34·0	(8·4) B. D. −2°·5668	19	+7·25	+61·5	"
11	21 46 53·78	−3 39 59·6	(6·0) 5894 Radcliffe 1890	21	+7·86	+61·6	"
12	21 47 16·37	−4 29 07·9	(7·0) 5895 Radcliffe 1890	22	+8·01	+67·5	"

Observations of Minor Planets made with the 15-inch Equatorial of the National Mexican Observatory, Tacubaya.

By Felipe Valle.

(*Communicated by the Secretaries.*)

Long. W. 6h 36m 46s.53. Lat. N. 19° 24′ 17″.5.

Date.	Tacubaya Mean Time.	Planet Δα.	Star Δδ.	No. of Comps.	Observer.	Planet App. R.A.	Log p×Δ of Parallactic Factor.	Planet App. Decl.	Log p×Δ of Parallactic Factor.	Red. to App. Place.		No. of Star.
						(176) *Idunna.*						
1894.	h m s	m s	′ ″			h m s		° ′ ″		s	″	
Oct. 3	11 32 58	+1 41.11	−1 5.84	5–5	F. V.	...	+7.971	...	+0.131	+3.44	+23.90	1a, 1
6	9 52 57	−1 17.21	−1 37.58	4–4	„	0 19 7.32	+9.302	+9 48 51.3	+0.191	+3.46	+24.15	2
8	11 20 3	−0 38.34	−0 26.80	6–6	„	0 17 55.23	+8.522	+9 20 5.3	+0.185	+3.46	+24.15	3a, 3b
9	10 6 56	−0 58.34	+4 16.35	6–6	„	0 17 22.80	9.129n	+9 6 52.4	+0.200	+3.48	+24.32	4
10	8 53 5	+2 1.00	−3 10.41	5–5	„	0 16 50.71	9.465n	+8 53 36.7	+0.251	+3.47	+24.24	5
11	8 47 29	−1 37.39	−6 22.32	6–6	„	0 16 17.94	9.419n	+8 39 43.4	+0.259	+3.48	+24.35	6
						(190) *Ismene.*						
Nov. 5	10 9 17	+1 0.93	+0 55.44	6–6	F. V.	2 18 23.57	9.213n	+8 5 4.8	+0.248	+3.82	+25.25	7

Date.	Tacubaya Mean Time.	Planet Δα.	Star Δδ.	No. of Comps.	Observer.	Planet App. R.A.	Log p × Δ of Parallactic Factor.	Planet App. Decl.	Log p × Δ of Parallactic Factor.	Red. to App. Place.		No. of Star.
						⑳ *Bellona.*						
1894.	h m s	m s	′ ″			h m s		° ′ ′		s	″	
Dec. 4	8 20 20	+0 51·35	−5 32·90	11–11	P. S.	5 21 30·67	9·694n	+8 49 4·3	+0·357	+4·39	+14·04	8
17	8 0 51	−0 28·79	+0 37·72	12–12	,,	5 9 30·79	9·638n	+8 57 18·8	+0·314	+4·55	+13·65	9
27	9 11 8	−1 2·07	+0 24·85	7–7	F. V.	5 0 52·31	9·302n	+9 21 15·9	+0·208	+4·62	+13·69	10
28	10 3 26	−1 50·54	+3 55·44	5–5	,,	5 0 3·86	8·807n	+9 24 35·6	+0·183	+4·62	+13·61	10
29	9 37 17	+2 30·36	−2 4·59	5–5	,,	4 59 17·91	9·066n	...	+0·187	+4·62	+14·03	11
						76 *Freia.*						
Dec. 28	9 4 40	+1 5·91	+1 43·66	6–6	F. V.	5 7 7·05	9·366n	+20 28 3·2	+8·703	+4·95	+14·62	12
29	8 47 40	+0 24·51	+0 44·93	8–8	,,	5 6 25·66	9·418n	+20 27 4·4	+9·072	+4·96	+14·63	12
30	8 41 46	+0 57·67	+0 31·62	5–5	,,	5 3 48·93	9·366n	+20 23 28·1	+8·786	+4·96	+14·95	13
						164 *Eva.*						
Dec. 31	10 1 2	+1 2·93	−0 36·05	7–7	F. V.	5 58 46·07	9·346n	+35 46 10·4	0·352n	+5·82	+ 9·72	14
1895. Jan. 2	9 37 3	−1 1·89	−1 29·48	7–7	,,	5 56 5·61	9·415n	+36 1 55·1	0·340n	+1·81	+ 9·89	15
3	9 6 15	+0 24·73	−2 31·27	7–7	,,	5 54 48·99	9·519n	+36 9 6·7	0·293n	+1·81	+ 9·98	16
4	10 56 11	+1 36·82	+0 36·85	4–4	,,	5 53 26·02	+7·486	+36 16 49·9	0·413n	+1·81	+10·22	17

Note.—The observations marked "P. S." were made by Señor Pedro Sanchez.

Comparison Stars.

No. of Star.	α 1894·0.	δ 1894·0.	Authority.	Date.	Observed—Calculated Δα.	Δδ.	Ephem.
			(176) *Idunna.*				
	h m s	° ′ ″			s	″	
1a	...	...	B. D. + 10°·39 (9·3)		...	...	Ast. Nach.
1	(1a + 1 31·64)	(1a − 3 50·02)	Anon. (10·5). Ref. to 1a		...	...	
2	0 20 21·07	+ 9 50 4·8	(8·6) A. G. Z. Leipzig	Oct. 6	+ 0·29	+ 6·1	„
3a	0 15 1·28	+ 9 20 55·85	(8 7) „ „		...	...	„
3b	0 18 30·11	+ 9 20 7·9	(10·0) = 3a + 3ᵐ 28ˢ·83 − 0′ 47″·94	8	+ 0·50	+ 3·6	„
4	0 18 17·66	+ 9 2 11·7	(8·7) A. G. Z. Leipzig	9	+ 0·45	+ 5·6	„
5	0 14 46·24	+ 8 56 22·9	(8 8) A. G. Z. Leipzig	10	+ 0·22	+ 4·3	„
6	0 17 51·85	+ 8 45 41·4	(8·7) A. G. Z. Leipzig	11	+ 0·38	+ 4·0	...
			(190) *Ismene.*				
7	2 17 18·82	+ 8 3 44·1	B. D. (8·2) + 7°·375 = ξ^2 *Ceti* $\left\{ \begin{matrix} -5^m\ 12^s{\cdot}55 \\ +4'\ 39''{\cdot}04 \end{matrix} \right\}$	Nov. 5	+ 8·57	+ 29·1	B. A. Jahrb.
			28 *Bellona.*				
8	5 20 34·93	+ 8 54 23·2	(8·4) Glasgow 1326	Dec. 4	+ 0·01	− 2·7	R. Luther.
9	5 9 55·03	+ 8 56 27·4	(8·3) Schjellerup 1693	17	− 0·42	+ 5·2	„
10	5 1 49·78	+ 9 20 26·5	(6·5) Cincinnati $_{12}$ − 313	27	+ 0·32	− 1·0	„
10	5 1 49·78	+ 9 20 26·5	„ „ „	28	+ 0·50	+ 4·2	„
11	4 56 42·93	...	(8·5) B. D. + 9°·711	29	− 1·40	...	„

No. of Star.	α 1894·0.	δ 1894·0.	Authority.	Date.	Observed—Calculated Δα.	Observed—Calculated Δδ.	Ephem.
			76 *Freia.*				
12	h m s 5 5 56·19	+20° 26′ 4″·9	B. D. +20°·900 (Merid. Circ., Tacubaya)	Dec. 28	+30ˢ·16	+28″·6	B. A. Jahrb., 1896.
12	5 5 56·19	+20 26 4·9	„ „	29	+30·18	+28·4	„
13	(13*a* −9ˢ·45)	(13*a* +3′ 28″·19)	B. D. +20°·889. Ref. to 13*a*		...	...	
13*a*	5 2 55·75	+20 19 13·4	B. D. +20°·890 (Tacubaya meridian)	30	+30·17	+28·1	„
			(164) *Eva.*				
14	5 57 37·32	+35 46 36·7	B. D. +35°·1328	Dec. 31	...	..	B. A. Jahrb.
	1895·0.	1895·0.		1895.			
15	5 57 5·88	+36 3 14·7	B. D. +36°·1344 = 15*a* $\begin{Bmatrix} -3^m\ 45^s\cdot10 \\ -1'\ 28''\cdot42 \end{Bmatrix}$	Jan. 2	+ 1·96	+ 1·93	„
15*a*	6 0 50·98	+36 4 45·0	Yarnall −2579		...	...	„
16	5 54 22·45	+36 11 28·0	Anon. = 16*a* $\begin{Bmatrix} -5^m\ 57^s\cdot66 \\ -5'\ 38''\cdot50 \end{Bmatrix}$	3	+ 2·06	+15·9	„
16*a*	6 0 20·11	+36 17 6 5	...		...	...	
17	5 51 47·39	+36 16 2·8	B. D. +36° 1317. Ref. to 15*a* & 16*a*	4	+ 2·07	+18·1	„

Errata.

Monthly Notices, vol. lv. page 290, last line but three :

for $G = 22^h\ 32^m$ *read* $G = 20^h\ 32^m$.

List of Presents, &c. 1894–95.

Page 276, 5th title from bottom :

for presented by the author *read* presented by Mr. M. C. Sharp.

Memoirs R.A.S. vol. li. page 90, last line :

for $l = a \sec \theta_2 = 2\lambda \sin \theta_2$ *read* $l = a \sec \theta_2$ simply (*i.e.* $de'e = 2\lambda \sin \theta_2$).

Page 91 :

dele lines 1 and 2.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. DECEMBER 13, 1895. No. 2

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

Major Kingsley Foster, Shenley, Red Hill, Surrey;
Rev. Henry A. Hall, M.A., Grammar-School, Totnes, Devon;
Rhishard Llewelyn Jones, M.A., Professor of Physics, Presidency College, Madras, India; and
Herbert Savery, M.A., Marlborough College, Wilts,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Cyril E. Ashford, M.A., Assistant Master, The School, Harrow (proposed by W. H. M. Christie);
Frank Arthur Bellamy, Assistant, University Observatory, Oxford (proposed by H. H. Turner);
Thomas Folkes Claxton, First Assistant, Royal Alfred Observatory, Mauritius (proposed by W. H. M. Christie);
Philip H. Cowell, B.A., Fellow of Trinity College, Cambridge (proposed by W. H. M. Christie);
Robert Fermor Rendell, B.A. (Lond.), The Glen, Blackheath Hill, S.E. (proposed by W. H. M. Christie);
George Albert Smith, St. Ann's Gardens, Brighton (proposed by J. H. Mitchiner); and
Charles Albert Taylor, 33 Argyle Street, Argyle Square, London (proposed by A. Fowler).

Eighty-three presents were announced as having been received since the last meeting, including, amongst others—

H. S. Davis, The Variation of Latitude at New York City, Part I., declinations and proper motions of fifty-six stars, pre-

sented by the author; Göttingen, Astronomische Mittheilungen der k. Sternwarte, IV. W. Schur, Oerter der helleren Sterne der Praesepe, presented by the Observatory; B. d'Engelhardt, Observations faites dans son observatoire à Dresde, III., presented by M. d'Engelhardt; C. Mönnichmeyer, Beobachtungen von Nebelflecken, presented by the Bonn Observatory; five original negatives of the Moon, and photograph of *Saturn*, presented by the Lick Observatory; lantern slide of the *Hercules* cluster, presented by Mr. W. E. Wilson; lantern slide from photograph of a meteor, presented by Mr. C. P. Butler; two photographs of the 28-inch equatorial, presented by the Astronomer Royal; photograph from a drawing of the Moon by John Russell, R.A., presented by Mr. E. J. Stone; and photograph of the nebula M 33 *Trianguli*, presented by Dr. Roberts.

The Mont Blanc Observatory.

The President and Council of the Royal Society have communicated to the Council of this Society the following letter from M. Janssen, which is printed here (according to a resolution of Council on December 13) for the information of Fellows:—

Meudon, 25 octobre, 1895.

Monsieur le Président,

J'ai l'honneur d'offrir à la Société le premier tirage du Compte Rendu de ma dernière ascension à l'Observatoire du Mont Blanc.

Je saisis cette occasion pour assurer aux savans anglais qui voudraient bien faire des travaux à l'Observatoire que nous ferions tout ce qui dépendrait de nous pour leur faciliter ces travaux dont nous serions heureux.

(Signed) J. Janssen.

A Universal Catalogue or Subject Index.

The following letters have been received from the Royal Society and referred by the Council of this Society to the Secretaries, as Editors of the Society's publications :—

I.

The Royal Society,
Burlington House,
December 3, 1895.

Dear Sir,

The International Catalogue Committee of the Royal Society, which is engaged in considering steps for the due indexing of scientific literature, has requested the Council of the

Royal Society to arrange that in the *Philosophical Transactions* and *Proceedings* of the Royal Society each paper should be accompanied by such a statement of its contents as would serve for use in the preparation of a subject index. If this were generally done the preparation of a subject index would be greatly helped, and I am directed by the Committee to suggest the same course of action to your Society, as well as to all the other principal scientific societies.

Yours truly,

M. Foster, Sec. R.S.

The Secretary,
Royal Astronomical Society.

II.

The second letter is a circular letter addressed by the Secretaries of the Royal Society to its Fellows (and others), illustrating more explicitly what is required.

Royal Society,
Burlington House, London, W.

Dear Sir,

Seeing that the title only of a paper is in most cases insufficient as a guide to its proper classification in a subject index—several topics, each demanding a separate entry, being often treated of in one paper—the President and Council of the Royal Society, with the view of facilitating the preparation of subject indices to scientific papers published by them, have resolved to ask every author communicating a paper to the Royal Society to add a condensed statement of the topics treated of, such as would facilitate the proper references to his paper in a subject index.

We subjoin a specimen statement which may help to explain what is intended.

We are,

Yours faithfully,

M. Foster, }
Rayleigh, } *Secretaries.*

BLACKMAN, F. F.

Original Title for Authors' Index.

Experimental Researches on Vegetable Assimilation and Respiration.
No. I.—New Method for investigating the Carbonic Acid Exchanges of Plants.
No. II.—Paths of Gaseous Exchange between Aërial Leaves and the Atmosphere.

Subject Index.
- **Assimilation, vegetable.**
- **Carbonic acid absorbed and given out by leaves, estimation of.**
- **" exhaled from leaves by stomata alone.**
- **" solubility in oils, &c.**
- **Gaseous exchanges in plants.**
- **Leaves, paths of gaseous exchange.**
- **Plants, gaseous exchanges of.**
- **Respiration, vegetable.**
- **Stomata, site of exhalation of carbonic acid.**

In accordance with the suggestions contained in these letters, the Secretaries would ask authors of papers intended for publication by this Society to enclose with each paper a "condensed statement of the topics treated of." It will probably be some little time before a satisfactory uniform system is arrived at, and the Secretaries will welcome any suggestions which may conduce to this desirable end. For the present the particulars furnished by the authors themselves will generally be printed as they stand; or if any additions are made by the Editors these will be clearly indicated.

E. W. MAUNDER, } *Secretaries.*
H. H. TURNER, }

Note on Hansen's Lunar and Planetary Theories. By Professor Ernest W. Brown.

The integration of the equations for the mean anomaly and the radius vector in Hansen's lunar theory depend chiefly on the calculation of a certain function W which has the value *

$$\overline{W} = -1 - \frac{h_0}{h} + 2\frac{h}{h_0}\frac{\overline{r}}{a_0}\frac{1 + e\cos(\overline{f} + n_0 yt + \pi_0 - \chi)}{1 - e_0^2}.$$

In this expression h, e, χ refer to the instantaneous ellipse, and therefore, in disturbed motion, they are implicit functions of the time; h_0, n_0, y, π_0 are absolute constants referring to a certain auxiliary ellipse, of constant size and shape, situated in the plane of the instantaneous orbit, the mean anomaly of this ellipse being denoted by $n_0 z$. In undisturbed motion, $n_0 z$ is of the form, $n_0 t$ + *const.*; in disturbed motion, $n_0 z$ contains, in addition, terms depending on the action of the Sun, and it is therefore a function of the time. The symbols $\overline{r}$, $\overline{f}$ denote the radius vector and true anomaly of the point on the auxiliary ellipse where the latter is cut by the radius vector of

* *Darlegung der theoretischen Berechnung, &c., Abh. der K. Sächs. Ges. der Wiss.* vol. vi. p. 104.

the Moon; they are therefore functions of the one variable z and thence of the time.

It is necessary to insert, in the above expression for $\overline{W}$, the disturbed values of h, e, χ; but instead of finding their values directly, Hansen differentiates W with respect to the time and then inserts the values of dh/dt, de/dt, $d\chi/dt$, thus reducing the three integrations to one. In performing the differentiation and subsequent integration of $\overline{W}$ he has shown that we may consider $\bar{r}, \bar{f}$ as constants. The proofs of the theorems* by which this result is obtained are long and, as regards the particular function of the elements used by Hansen, unnecessary; the theorem can, in fact, be shown to be a simple application of the integral calculus.

The above expression for $\overline{W}$ may be put into the form

$$\overline{W} = L_1 + L_2\bar{r} + L_3\bar{r}\cos\bar{f} + L_4\bar{r}\sin\bar{f},$$

where L_1, L_2, L_3, L_4 contain t only through h, e, χ, n_0yt. In the expressions for $\bar{r}, \bar{f}$ in terms of z (or of t), suppose that t be replaced by τ and z by ζ, and let $\bar{\rho}$, $\bar{\phi}$ denote the resulting expressions of $\bar{r}, \bar{f}$. Then, considering τ, and therefore ζ, as constant, we may write

$$\begin{aligned} \overline{W} &= \int\frac{dL_1}{dt}dt + \bar{r}\int\frac{dL_2}{dt}dt + \bar{r}\cos\bar{f}\int\frac{dL_3}{dt}dt + \bar{r}\sin\bar{f}\int\frac{dL_4}{dt}dt \\ &= \left[\int\left\{\frac{dL_1}{dt} + \bar{\rho}\,\frac{dL_2}{dt} + \bar{\rho}\cos\bar{\phi}\,\frac{dL_3}{dt} + \bar{\rho}\sin\bar{\phi}\,\frac{dL_4}{dt}\right\}dt\right]_{\tau=t} \end{aligned}$$

If, then, we denote by W the value of $\overline{W}$ when $\bar{\rho}$, $\bar{\phi}$ replace $\bar{r}, \bar{f}$ in the expression first given, we have

$$\overline{W} = \left[\int\frac{dW}{dt}dt\right]_{\tau=t}.$$

That is to say, the expression for $\overline{W}$ can be differentiated, the disturbed values of the elements substituted, and the resulting expression integrated, with $\bar{r}$, $\bar{f}$ constant during the whole process. The object of the introduction of τ, $\bar{\rho}$, $\bar{\phi}$ is merely to prevent confusion between the quantities which remain variable and those which are considered constant.

The same result is available in the planetary theory,† but it is somewhat simplified by the absence of the term n_0yt.

Haverford College, Pa.:
1895 October 9.

* *Fundamenta nova, &c.*, pp. 22–25. *Commentatio de corporum cœlestium perturbationibus. Astr. Nach.* vol. xi. col. 322.

† *Auseinandersetzung einer zweckmässigen Methode, &c., Abh.* vol. v.

Note on the Discovery of the Graphical Method for Solving Kepler's Equation by means of a Curve of Sines. By T. J. J. See, A.M., Ph.D. (Berlin).

Through the courtesy of the Secretary, Dr. K. Zelbr, of Brünn, recently of the Imperial Observatory of Vienna, has called my attention to the fact that the method for solving Kepler's Equation by means of a curve of sines, given in the *Monthly Notices* for June, and usually attributed to Dubois, of Brest, was in reality discovered by an Englishman, J. J. Waterston, Esq. A short abstract of his paper appears in the *Monthly Notices* for 1849–50, p. 169, and is entitled, "On a Graphical Mode of Computing the Eccentric Anomaly." Dr. Zelbr writes that this error in regard to the original discoverer occurs in several standard astronomical works, notably in Wolf's *Handbuch der Astronomie*, and Klinkerfues' *Theoretische Astronomie*, from which it seems fairly certain that Waterston's discovery of this important method has been generally overlooked.

Klinkerfues' discussion first directed my attention to the method, and as Dubois in *Astron. Nachr.* 1404 makes no mention of any previous discovery, I assumed with Klinkerfues that Dubois had been the first to detect the possibility of such a solution. It is clear, however, from the concise abstract printed in the *Monthly Notices* for 1849–50, that Waterston had preceded Dubois by about fourteen years; and while Dubois' discovery seems to have been independent of Waterston's, the latter has the undoubted right of priority.

I cannot but remark how singular it is that a method of such great practical importance should rest in comparative oblivion during half a century at a time when astronomers were constantly working on the motions of periodic comets and double stars; but it is probable that neither Waterston nor Dubois recognised the great generality and high value of the method in practical work. Since writing the paper which I communicated to the Society at the June meeting I have had occasion to make great use of the method in revising the orbits of double stars, and have found it, not only the easiest and most rapid process yet invented, but one altogether so satisfactory that we may predict its universal adoption by astronomers. The simplicity and generality of the method and the rapidity and accuracy with which solutions can be obtained invite the inference that in the nature of the case the method is probably ultimate, and is not likely to be improved upon in any future age.

The true history of an important discovery is always interesting, and while Waterston's work does not diminish the credit

due to Dubois for an independent result, it will yet be gratifying to the present Fellows of the Society to know that the original discovery was made by a countryman and a contemporary of Sir John Herschel.

The University of Chicago:
1895 October 22.

Micrometrical Determinations of the Diameters of the Minor Planets Ceres (1), *Pallas* (2), *Juno* (3), *and Vesta* (4), *made with the Filar Micrometer of the 36-inch Equatorial of the Lick Observatory, and on the Albedos of those Planets.* By E. E. Barnard.

In *Monthly Notices of the Royal Astronomical Society*, vol. liv. No. 9, I have given a series of micrometer measures of the diameters of the asteroids *Ceres* (1), *Pallas* (2), and *Vesta* (4) made with the great telescope.

These measures have been continued this year, except in the case of *Pallas*, whose greatly increased distance discouraged any measures of it.

I have also secured measures of *Juno* on four nights. The disc of this object, however, was extremely small, and so nearly the size of the spurious disc of a star of the same magnitude that it must for the present, perhaps, be taken as showing only the possible maximum diameter.

I am confident, however, that the real disc was seen, as it seemed to sensibly enlarge with the higher powers.

On each night, while under observation, this asteroid was micrometrically referred to some star near it for motion, so that no mistake was possible in its identification.

Ceres has been running very far south—some 28° of south declination. This has made it rather difficult; but no measures were attempted unless the disc was clearly seen.

The measures were made with 1,000 diameters, except in one or two instances, when 1,500 was used. On one or two occasions 2,600 was also employed. But 1,000 was found more uniformly satisfactory.

For completeness of this paper I have added to these measures my observations of 1894 (including those of *Pallas*).

Micrometrical Measures of the Diameters.

Ceres (1).

		Obsd.	At Δ 2·7673.	δ
1894. Mar.	12	0″·75	0″·44	−0″·05
	25	0·72	0·43	−0·04
Apr.	1	0·73	0·44	−0·04
	9	0·58	0·36	+0·03
	16	0·60	0·39	0·00
	23	0·59	0·40	−0·01
	30	0·58	0·40	−0·01
May	7	0·47	0·34	+0·05
1895. May	12	0·53	0·40	−0·01
	13	0·56	0·42	−0·03
June	2	0·60	0·41	−0·02
	3	0·56	0·39	0·00
	17	0·67	0·45	−0·06
	23	0·47	0·32	+0·07
	24	0·64	0·43	−0·04
	30	0·48	0·32	+0·07
July	1	0·63	0·43	−0·04
	7	0·62	0·43	−0·04
	8	0·48	0·33	+0·06
	14	0·55	0·38	+0·01
	15	0·57	0·40	−0·01
Aug.	4	0·44	0·33	+0·06
	5	0·43	0·32	+0·07
			0·389	

or at Δ1 = 1″·076.

In the measures of *Ceres* in 1894 I have omitted the observation of March 11, as all the other measures show it was too large.

Pallas (2).

		Obsd.	At Δ 2·7673.	δ
1894 Feb.	25	0″·75	0″·34	−0″·10
	26	0·59	0·26	−0·02
Mar.	11	0·44	0·21	+0·03
	12	0·46	0·21	+0·03
	25	0·40	0·20	+0·04
			0·244	

or at Δ1 = 0″·675.

Juno (3).

		Obsd.	At Δ 2·7673.	δ
1895. July	21	″ 0·16	″ 0·11	″ −0·02
	22	0·14	0·10	−0·01
Aug.	4	0·12	0·09	0·00
	5	0·11	0·08	+0·01
			0·095	

or at Δ1 = 0″·263.

Vesta (4).

		Obsd.	At Δ 2·7673.	δ
1894. Mar.	11	″ 0·38	″ 0·23	″ −0·04
	12	0·46	0·22	−0·03
	25	0·33	0·16	+0·03
Apr.	1	0·39	0·20	−0·01
	9	0·29	0·15	+0·04
1895. July	7	0·35	0·19	0·00
	8	0·44	0·24	−0·05
	14	0·41	0·21	−0·02
	15	0·42	0·22	−0·03
	21	0·38	0·19	0·00
	22	0·38	0·19	0·00
Aug.	4	0·40	0·19	0·00
	5	0·42	0·20	−0·01
	11	0·43	0·20	−0·01
	12	0·35	0·17	+0·02
	18	0·43	0·20	−0·01
	19	0·40	0·19	0·00
	25	0·40	0·19	0·00
			0·195	

or at Δ1 = 0″·540.

δ in each case is the deviation from the mean.

No correction has been applied for irradiation, since it is not only an unknown quantity, but must also be inappreciable in these measures. No correction has been applied for phase, because the measures were made at and near opposition, and the correction would be insensible.

Collecting the results, we have for the diameters of

	At Δ 2·7673.	At Δ1.
	"	"
Ceres	0·389	1·076
Pallas	0·244	0·675
Juno	[0·095]	[0·263]
Vesta	0·195	0·540

Reduced to English miles, these become, for

Diameter of	Ceres (1) =	485	miles
„	Pallas (2) =	304	„
„	Juno (3) =	[118]	„
„	Vesta (4) =	243	„

In comparing the measures for the two years, it will be seen that in the main they are perfectly accordant. Those of the present year were not reduced until the close of the work. The observations are therefore free of bias.

These results, I believe, are very accurate, and I think we have now for the first time satisfactory information of the dimensions of at least three of the four brightest asteroids. I feel sure that the diameters of *Ceres, Pallas*, and *Vesta* are now as well known as are those of the four bright moons of *Jupiter*.

I hope to take up the measurement of these bodies with more powerful optical means in the near future, and, if possible, extend the list to other members of the asteroidal group. In the winter of 1896 *Juno* will be very favourably placed for measurement, and I shall hope then to get good measures of it.

Previous Efforts to determine the Diameter of these Asteroids.—A friend has called my attention to a recent paper by Mr. H. Sadler, containing a collection of the various previous efforts to determine the diameters of these four asteroids. Mr. Sadler's paper can be found in the *English Mechanic* for August 2, 1895, p. 533.

Because of the importance of the subject, I will copy here the results he gives for previous observations.

Ceres (1).

Schröter (diameter) ...	1,570 miles	Bruno ...	227* miles
Wm. Herschel ...	162 „	Galle ...	396 „
Argelander	225* „	Knott ...	630 „

Pallas (2).

Schröter	2,025 miles		
Wm. Herschel	122 „		
„ also 83 and 70 miles, "almost incredibly small."			
Lamont ...	667 miles	Bruno ...	171* miles
Argelander ...	158* „	Pickering ...	167* „

Juno (3).

Schröter ...	1,380 miles	Stone ...	124* miles
Argelander ...	105* „	Pickering ...	94* „
Bruno ...	115* „		

Vesta (4).

Schröter ...	333 miles	Secchi ...	450 ± miles
Mädler ...	290 „	Tacchini ...	880 „
Argelander ...	270* „	Millosevich	630 „
Bruno ...	230* „	Pickering ...	319* „
Stone ...	214* „		

The diameters marked with an asterisk (*) were derived by photometric means.

The general agreement of these photometric values is doubtless due to essentially the same data being employed by each of the astronomers.

Mr. Sadler had evidently not seen Dr. G. Müller's elaborate photometric observations of three of these four asteroids—viz. *Ceres*, *Pallas*, and *Vesta*. Dr. Müller's work comprises No. 30 of the Publications of the Astrophysical Observatory of Potsdam, 1893. He deduces the dimensions of these three bodies on two suppositions. First, that their albedo is equal to that of *Mercury*; second, that it is equal to that of *Mars*.

His results are :—

	I. Radius.	II. Radius.
Ceres	475 kilom.	379 kilom.
Pallas	354 „	282 „
Vesta	473 „	377 „

These give the following *diameters* in English miles :—

	I.	II.	Means.
Ceres	594 miles	474 miles	534 miles
Pallas	442 „	352 „	397 „
Vesta	591 „	471 „	531 „

The uncertainty of the photometric method in determining the dimensions of these bodies is well shown by the large differences in the results derived by even this moderate range of assumed albedo.

In reality there is a very wide range of albedo among the asteroids themselves—at least as great as that found among the planets.

This is not surprising, for even in so closely related bodies as the four bright moons of *Jupiter*, there is a very great range of albedo.

From my measures it is now possible to determine the albedos of these four asteroids with considerable precision.

Professor Arthur Searle, of the Harvard College Observatory, has kindly supplied me with the photometric magnitudes of *Ceres*, *Pallas*, *Juno*, and *Vesta*, as determined at Harvard College Observatory, and by Mr. H. M. Parkhurst at Brooklyn, N.Y.

These values, reduced to mean opposition and to distance unity, are:—

	At M. Opp. m.	At Δ1. m.
Ceres.		
H.C.O. Merid. Photom. Observers, Pickering and Wendell (15*n*)	7·72	4·27
Brooklyn, N.Y. H. M. Parkhurst	...	3·74
H.C.O. Wedge Photom. Observer, Wendell (16*n*)	7·24	3·84
Pallas.		
H.C.O. Merid. Photom. Pickering and Wendell (17*n*)	8·48	5·02
Brooklyn, N.Y. H. M. Parkhurst	...	4·50
Juno.		
H.C.O. Merid. Photom. Pickering and Wendell (15*n*)	9·50	6·26
Brooklyn, N.Y. H. M. Parkhurst	...	5·77
Vesta.		
H.C.O. Merid. Photom. Pickering, Searle, and Wendell (22*n*)	6·47	3·93
Brooklyn, N.Y. H. M. Parkhurst	...	3·49
H.C.O. Wedge Photom. O. C. Wendell (23*n*) ...	6·79	4·25

Müller's photometric values from the Potsdam observations are:—

	At Δ1. m.		At Δ1. m.
Ceres	3·46	Vesta	3·47
Pallas	4·10		

The means of these different determinations are :—

	At Δ 1.		At Δ 1.
	m.		m.
Ceres	3·83	Juno	5·91
Pallas	4·55	Vesta	3·79

It will be seen that these various determinations by different observers differ in some cases by nearly an entire magnitude.

Albedos.—Müller gives the magnitude of Mars = − 1·297.

From the above values of the magnitudes I have derived, from my diameters, the following albedos of these four asteroids :—

Albedos (Mars = 1·00).

Ceres	0·67	Juno	1·67
Pallas	0·88	Vesta	2·77

Müller has determined the albedos of the various planets, and it is interesting to compare these with the above.

Albedos and Magnitudes of the Planets (Müller).

	Albedo.	Mag. at Δ 1.
Mercury	0·64	−0·003
Venus	3·44	−4·004
Mars	1·00	−1·297
Jupiter	2·79	−8·932
Saturn	3·28	−8·685
Uranus	2·73	−6·858
Neptune	2·36	−7·053

By comparison, it will be seen that the surface of *Ceres* reflects light with about the same intensity as that of *Mercury*, *Pallas* somewhat less than *Mars*, *Juno* between that of *Mars* and *Jupiter*, while *Vesta* is about equal to that of *Jupiter*.

The mean albedo of the four is 1·45. This value will be a far safer standard to use in the determinations of the dimensions of the other asteroids by photometric methods than that previously adopted.

Up to the making of these measures with the 36-inch, *Vesta* was considered, from its generally greater brightness, to be the largest of the asteroids. It is now understood, from its high albedo, why it was so bright. Its surface reflects light with four times the intensity of that of *Ceres*.

It will also be readily seen that *Ceres* is really by far the largest of the asteroids.

In conclusion, I think it is scarcely necessary to add that all previous attempts at direct measures of the diameters of these small bodies were made with instruments inadequate to deal satisfactorily with such minute quantities as the asteroidal

diameters. They are far more difficult to deal with than the four bright moons of *Jupiter*.

Relative sizes of the four bright asteroids and the Moon (the inclosing circle is the Moon).

To make the relative sizes of these four asteroids apparent at once to the eye, I give a diagram made from my measures.

Professor Tucker, of the Lick Observatory, kindly and specially observed the magnitudes of these four asteroids for me with the meridian circle of the Lick Observatory. It was my intention to incorporate these visual magnitudes with the photometric values in deducing the albedos of *Ceres*, *Pallas*, *Juno*, and *Vesta*; but I finally decided to use the photometric results alone, as the albedos of the planets had been so determined by Dr. Müller. Professor Tucker's great experience in estimating magnitudes in his valuable work in observing the Cordoba D.M. will make these estimations valuable.

I herewith append his results.

Estimations of the Magnitudes of Ceres, Pallas, Juno, and Vesta.
By R. H. Tucker, Jun., 1895.

1895 July 26	Ceres	8 mag.	1895 July 31	Pallas	8½ mag.
26	Juno	8½ mag.	31	Vesta	6¾ mag.

These are the observed magnitudes, and will be on the same scale as those of the Cordoba D.M.

Mount Hamilton, California:
1895 *August* 29.

On the Extended Nebulosity about 15 *Monocerotis.*
By E. E. Barnard.

I am somewhat surprised at Dr. Roberts' statements in *Monthly Notices*, vol. lv. No. 7, for May 1895, where he condemns the idea of the diffused nebulosity shown about 15 *Monocerotis* on my photograph of 1894 February 1.

I must also object to the unjust comparison that he has made. He has shown upon the screen a lantern slide made from my glass positive of this region, which is in the possession of the R.A.S. This he has enlarged some four or five times to compare with his *unenlarged* photograph. He finds under these conditions that my picture is coarse, and that the nebulosity to which I called attention is not real, but is due to diffused light from many small stars.

I would say that these pictures, made with a short focus lens, are not intended to be enlarged, or, if so, but slightly. If the subjects are wanted on a larger scale the best plan is to use a longer focus and bigger telescope for that purpose—such, for instance, as Dr. Roberts' reflector.

They are intended to be looked at and studied as *pictures* of the regions they show, and are not to be examined microscopically. It is unjust to use an enlargement such as Dr. Roberts used, because it necessarily puts these pictures at a disadvantage. My picture was simply spoiled by this, while Dr. Roberts retained its original qualities, not being enlarged.

An enlargement should not be made from a copy, but from the original, because a copy like this was made with special reference to showing the nebulosity; the stars therefore suffer, especially if an enlargement is made.

A short focus lens like this is not intended to show small details because of its small scale. The study of small details belongs specially to large telescopes. The short focus lens, however, is exceptionally fine for just such large diffused nebulosities as that surrounding 15 *Monocerotis.*

Dr. Roberts seems to forget, in speaking of my paper in *Astronomy and Astro-Physics*, vol. xiii. pp. 178–182, that it was I who called his attention to the fact that 15 *Monocerotis* was really nebulous, and that the closer nebulosities about this star were the special province of larger telescopes than mine.

I shall quote from the article in *Astronomy and Astro-Physics*:—

"Another photograph of the region about 15 *Monocerotis* on February 1, 1894, with three hours' exposure, shows the great nebula that envelopes 15 *Monocerotis* very much better than the previous picture. Its full extent—in diameter—can be taken roughly at 3°. It clusters densely about the groups of stars and then spreads out in a weak, diffuse light with rifts in it and irregularly terminated along the edges of a vast vacancy in the Milky Way. The condensation, which is very strong, is not at 15 *Monocerotis*, but 12′ south preceding that star, where it becomes a compact mass, with numerous wisps and holes in it. The whole group of three or four bright stars are involved in this denser wispy light, but 15 *Monocerotis* itself does not seem to be specially connected with the nebulosity further than to be apparently in it—that is, there are no indications of condensation about this the brightest star of the group. *This remarkable nebula—the denser part of it—is worthy of study with a more powerful photographic telescope. The condensed part of the nebula is only a few minutes in diameter, but it would readily photograph in a large instrument.* The place of 15 *Monocerotis* for 1860·0 is

$$\alpha = 6^h\ 33^m\ 16^s + 10°\ 1'{\cdot}3.$$

It is thus described in the catalogue (N.G.C.) '15 *Monoc.* Cl.⁎, ? neb.'"

It will be seen by the italicised portion of this description that I was fully aware of the inability of the Willard lens to deal with the closer details of this nebula, and I suppose this really called Dr. Roberts' attention to the object.

The glass positive I sent to the R.A.S. does not show the details of this nebula close to 15 *Monocerotis*, though much detail is shown on the original negative, because, as I have said, my aim was to show the diffused nebulosity, which required a different treatment.

I forward to the Society three paper prints from an enlargement from the original negative. These pictures are printed to different depths to show the diffused nebulosity.

Dr. Roberts states that "there are vast areas on the camera plate photographed, which, to most of us, would be accepted as evidence of nebulosity with dark tortuous rifts in it, but it is not nebulosity at all. It is, in fact, the effect of the diffused light of numerous and close stars being concentrated upon the photo-film by a small instrument, and the dark rifts are only areas with fewer stars in them, by causing the appearance that the crowded star areas are involved in true nebulosity." It will be noticed that this statement cannot strictly hold in the face of the facts shown by these prints.

By examining these pictures I send, it will be seen that Dr. Roberts' reasoning is decidedly wrong.

This diffused light is in nowise confined to the star areas. It will be also readily seen that it spreads over a large region where

there are essentially no stars at all—even where Dr. Roberts' reflector can show no stars.

That this is real diffused nebulosity there is no reason whatever to doubt. The photograph shows that it begins gradually to diffuse from 15 *Monocerotis* and spreads out over a large region covering star areas and vacancies for some degrees. I think an unprejudiced inspection of these prints will prove these statements.

As a further proof that this cannot be nebulosity which his 20-inch fails to show, Dr. Roberts says his photograph shows faint stars not on my positive, though the exposure was the same.

This proof is a rather surprising one. So far as the stars are concerned, Dr. Roberts gets the full effect of the light area of a 20-inch over that of a 6-inch. It is not at all unreasonable, therefore, that he should get fainter stars than I do in the same time, for the relative light areas are as 36 to 400, the quantity of light in his case being some eleven times greater.

But when it comes to nebulous areas quite a different condition prevails, and this I do not think will follow any special law of aperture and focus.

I should expect by all means to photograph large diffused nebulous masses quicker and better with the Willard lens than with a 20-inch reflector, though the reflector ought certainly to show fainter stars.

As an illustration of this matter of photographing large diffused areas of feeble light I would refer to some photographs made with a very small lens of $1\frac{1}{2}$ inch diameter. Compared with the Willard lens the light ratio of this small lens is about $\frac{1}{8\cdot5}$ to $\frac{1}{5}$. Instead of the smaller lens being some two times as quick on large faint areas of light, it is really upwards of fifteen or twenty times as quick, if we are to take the testimony of actual work made for the past year.

But I cannot see that there is any special reason to contest for the existence of this nebulosity, for we find similar areas of nebulosity elsewhere in the Milky Way that have passed unquestioned.

In conclusion let me add that both the Willard lens and Dr. Roberts' reflector have each their special field, which in nowise conflict, but in which they mutually supplement each other for the benefit and advancement of truth and knowledge.

Mount Hamilton, California:
1895 *September* 6.

Invisibility of Hind's Variable Nebula (N.G.C. 1555).
By E. E. Barnard, D.Sc., A.M.

In *Monthly Notices*, No. 8, vol. lv. pp. 442–452, I have given an historical account of the variable nebulæ of Hind and Struve (N.G.C. 1555 and 1554). I have also given the observations and measures of Mr. Burnham and myself of these two objects.

I have naturally become very much interested in these nebulæ, and have taken the first favourable opportunity to examine the region again with the 36-inch.

To my surprise no trace of Hind's nebula now exists—it seems to have entirely vanished! I have examined the place of this object several mornings lately under the very best conditions, but the variable nebula could not be seen.

τ *Tauri* was identified with certainty on each occasion. To be absolutely sure of the identification I again measured its position with reference to the W.B. star $4^h{\cdot}274$ south preceding it.

1895·73 $\Delta\delta$ (τ Tauri – WB $4^h{\cdot}274$) = $+243''{\cdot}66$

1895·73 $\Delta\alpha$ ( ) = $+0^m\ 16^s \pm$.

I also measured the $\Delta\delta$ between the small 14^m star, which stands in the position assigned the Struve nebula and the W.B. star.

1895·73 $\Delta\delta$ (14^m ✱ – WB $4^h{\cdot}274$) = $+189''{\cdot}27$.

These measures are in perfect accord with those in the article above referred to, and the identification is complete. The place was also in perfect accord with the diagrams in *Monthly Notices*, No. 8, vol. lv. pp. 444–450.

Every means was tried to see Hind's nebula: τ *Tauri* was occulted, the place was examined with averted vision, but no strain of eyesight could detect any trace of the nebula. If it had been as bright as at the observations in February last it would have been easily visible, as the conditions for seeing it were better. This proves my conjecture that this nebula still fluctuates in its light. It is certainly now invisible in the 36-inch. The place of this object should therefore receive careful attention with powerful telescopes to see when the nebula reappears.

With the utmost difficulty I could see an excessively faint star about $10'' \pm$ south of the Struve star. It could not be brighter than the 17 mag., as it was at the very limit of the 36-inch. I could not be certain that this faint object was really stellar; sometimes it looked nebulous. It is impossible, however,

to decide as to the nebulous condition of an object of this kind when at the limit of visibility.

τ Tauri was about as bright as the star A of my former paper, and seemed to be involved in a small hazy nebulosity; but the definite nebula in which it shone in 1890 did not exist.

These observations have been made under the best conditions, with the objects on the meridian, upon the following dates:—

1895 September 15, 22, and 23.

Mount Hamilton, California:
1895 *September* 24.

Note on some Remarks of Mons. O. Callandreau in the "Bulletin Astronomique" for November 1895. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

In the *Bulletin Astronomique* for November 1895, p. 458, there are some remarks by Mons. O. Callandreau, which bear upon my papers on time measurement. But as my papers on this subject have nearly all been printed in the *Monthly Notices*, it is, perhaps, desirable that the few words which I consider necessary in the way of reply should also appear in these publications.

M. Callandreau states, with perfect accuracy, that I base my measures of t, fundamentally, upon the Sun's mean longitude. But he expresses himself as follows:—

"On voit dans l'article dont il s'agit que M. Stone, rompant avec l'habitude des astronomes de mesurer le temps par l'angle horaire du Soleil, procède comme si la longitude moyenne du Soleil devait servir à la mesure du temps.

"Les deux manières sont également admissibles à un point de vue abstrait."

I have given this statement in M. Callandreau's own words on account of its importance.

I hardly think, however, that this statement, *as it will generally be understood*, can be accepted as correct.

If astronomers did, as a matter of fact, consistently and exclusively use a system of time-measures, t', which had no connection whatever with the system of time-measures, t, based on the Sun's mean motion in longitude, which I employ, then it might be possible to admit that my views were mathematically sound, but of no practical importance in the existing state of astronomy. But I have proved, or profess to have proved—whether rightly or wrongly may now be taken as the real point at issue—that astronomers *use in their mathematical investigations* measures of time, t, based directly on the Sun's mean motion in longitude; and, if there is any change of usage, which I assert to be the case, it is they who break away from the fundamental

system of time-measures, t, in terms of which their mathematical formulæ are expressed; when, on account of the practical difficulties in finding the variable, t, directly from the observations of the Sun, they attempt to determine it from the motion of the meridians in right ascension, or from the relative motions of the meridians and of the Sun in right ascension. Such methods of finding the variable, t, are things much to be desired. And they would be practically successful, for all the values of n' which could be adopted in our theoretical investigations, if the rotation of the Earth on its axis was, as is supposed, constant and the exact *ratio* of the mean motion of a meridian to that of the Sun in R.A. was known. But such is not the case. And the required variable, t, cannot, therefore, be *accurately found* in either of these ways. I believe this is now generally acknowledged.

Approximate values of t can be and are thus found by the use of approximate values of the *ratio* already referred to. But in estimating the errors made by the process adopted, it is necessary to take the error of the adopted value of the constant *ratio* into consideration.

This is what I have done in all my formulæ; and this is what astronomers have hitherto neglected to do. But the terms which I have added to the expression of the R.A. of a meridian as a function of t are certainly required if the measure of the time, t, is based on the Sun's mean longitude. If such had not been the case my formula would have been proved to be erroneous long before this.

To disprove the practical bearing of my views, it is necessary, therefore, that someone should show that astronomers do not establish a connection between the unit in terms of which t measures the time in their mathematical expressions, and n', *the Sun's mean motion in longitude in the unit of time*, when they eliminate from the differential equations of motion the accelerating effects of the mass of the Sun, m', or of the sum of the masses of the Sun and of the Earth, $m'+\mathrm{E}$, or the sums of the masses of the Sun, Earth, and Moon, $m'+\mathrm{E}+m$, by conditional equations such as

$$m'=a'^3n'^2$$

or

$$m'+\mathrm{E}=\mathrm{A}'^3n'^2$$

or

$$m'+\mathrm{E}+m=\mathrm{A}''^3n'^2\,;$$

assume the ratios of the accelerating effects of all the masses to that of the Sun to be constants independent of the units of length and of time, a condition which requires the same units of length and of time to be adopted in all the mathematical expressions; and find the connection between the linear constants a', or A', or A'', and the Sun's distance r', and those between the corresponding results of observation and the other linear and

angular quantities which appear in their mathematical work subject to one of the conditions mentioned.

I feel some confidence from the serious consideration which I have given to the question, that not only cannot this be shown, but that I have clearly shown the converse to be true. These proofs can be made absolutely rigorous, but they necessarily become somewhat long and formal if every elementary step has to be given.

Note on Newcomb's Tables of the Sun. By A. M. W. Downing, M.A., D.Sc.

Remarking on the large annual term exhibited in the comparison of Le Verrier's and Newcomb's Solar Tables, printed in the supplementary number of the *Monthly Notices* (vol. lv.), Professor Newcomb has pointed out to me that the definitive correction to Le Verrier's value of the eccentricity of the Earth's orbit for 1900, as found in his *Elements and Astronomical Constants* and adopted in the Solar Tables, is $+0''\cdot20$. The effective correction to Le Verrier's longitude of perigee for the same epoch is $+6''\cdot3$.

Calling these quantities δe and $\delta\pi$ respectively, we have the corresponding correction to the longitude:

$$\delta l = \frac{dl}{de} \cdot \delta e + \frac{dl}{ed\pi} \cdot e\delta\pi.$$

But

$$\frac{dl}{de} = \quad 2 \sin g$$

$$\frac{dl}{ed\pi} = -2 \cos g$$

where g is the mean anomaly.

Therefore,

$$\delta l = +0''\cdot40 \sin g - 0''\cdot21 \cos g.$$

Applying this correction to the comparison referred to above, we have (taking the mean of each three consecutive corrections for convenience) :—

Date 1900.	Residual Correction.	Date 1900.	Residual Correction
	$''$		$''$
Jan. 9	−0·27	July 20	−0·53
Feb. 2	−0·25	Aug. 13	−0·62
26	−0·26	Sept. 6	−0·57
Mar. 22	−0·33	30	−0·60
Apr. 15	−0·42	Oct. 24	−0·66
May 9	−0·42	Nov. 17	−0·73
June 2	−0·40	Dec. 11	−0·65
26	−0·46	27	−0·73

By the application of the corrections for eccentricity and longitude of perigee, the outstanding corrections become, therefore, corrections of a sensibly progressive character throughout the year under consideration. These progressive corrections arise doubtless from differences in the tables of perturbations given by Newcomb and Le Verrier respectively.

Photograph of the Spiral Nebula M. 33 Trianguli. By Isaac Roberts, D.Sc., F.R.S.

The photograph of the spiral nebula M. 33 *Trianguli*, R.A. $1^h\ 28^m$, Decl. 30° 7′ north, was taken with the 20-inch reflector on 1895 November 14, with exposure of the plate during 2 hours and 15 minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The nebula is N.G.C. No. 598, G.C. No. 352, h 131, Rosse, *Obs. of Neb. and Cl. of Stars*, p. 20; *Phil. Trans.* 1850, pl. 36, fig. 5, and 1861 pl. 36, fig. 10.

Sir J. Herschel (G.C. 352) describes the nebula as a remarkable object, extremely bright, extremely large, round, very rich, very gradually brighter in the middle with a nucleus, and resolvable.

Lord Rosse (references given above) has recorded 32 observations made between the years 1849 and 1862, and gives a marginal sketch. These make us acquainted with the difficulties encountered by the observers in their efforts to make intelligible, by descriptive matter and by drawings, an object having a structure so complex that no eye and hand, however well trained, could possibly delineate it.

The photograph shows the nebula to be a spiral with remarkable features. The nebula measures about 62 minutes of arc from *north following* to *south preceding*, and 35 minutes from *south following* to *north preceding*.

It will be observed that there are two large, very prominent, spiral arms, with their respective external curvatures facing north and south, and that the curves are approximately symmetrical from their extremities to their point of junction at the centre of revolution, where there is a nebulous star of about tenth magnitude with dense nebulosity surrounding it, and elongated in *north* and *south* directions. Involved in this nebulosity are three bright stars and several faint nebulous stars; the two arms also are crowded with well-defined stars and faint nebulous stars with nebulosity between them; and it is to the combined effect of these that the defined forms of the arms are due. Besides these two arms there are subsidiary arms, less well defined, and likewise trending towards the centre of revolution, and are constituted of interrupted streams of faint stars and nebulosity intermingled

together; many of the stars are nebulous and many are well defined but small. The interspaces between the convolutions are more or less filled with faint nebulosity, having curves, rifts, fields, and lanes, without apparent nebulosity in them. They are like the interspaces in clouds of smoke, and cannot be classified.

There are outliers of nebulosity with many small well-defined and nebulous stars involved in them, and there are also isolated nebulous stars on the extreme boundaries of the nebula; but the evidence is strong that they are all related to the nebula.

It is by the study of the photographs, and not by descriptive matter, that we can form a true conception of the character of this nebula; from which we shall be justified, even now, in drawing some inferences as to its formation and further developments. To this end I may be permitted to suggest the following.

We know, with a reasonable amount of certainty, that both nebulous and meteoric matters exist in space; and we also have some evidence that bodies in space have come into collision.

From these premises we may infer that this nebula is the result of a collision of some kind; and we can imagine collisions of at least three kinds possible; namely, (1) between two stars, (2) between two nebulæ, (3) between two swarms of meteorites.

In the case of this nebula, which (if any) of the three possibilities mentioned seems to us the one most probable to have happened? Much might be said in favour of each of these suggestions, but I shall not at present enter into details, though I think we could readily imagine that the collision of two swarms of meteorites, moving in opposite directions, one from the *south following* and the other from the *north preceding*, would account for the spiral appearance, the rotary motion, and the smashed and scattered state in which the nebula is shown to us upon the photographs.

Two photographs of the nebula have been taken, one on 1891 November 11, and the present photograph on November 14 (last month). I have examined these with some care, and found all the stars and the nebulosity, on both plates, to be sensibly coincident, after the lapse of an interval of four years; and unless the object were comparatively near to us, this result is what we should expect to find.

The spiral nebulæ M. 101 *Ursæ Majoris* and M. 74 *Piscium*, photographs of which we will now project on the screen, are very similar in character to M. 33 *Trianguli*; but they are more symmetrical in outline, and appear to have arrived at a more advanced stage in their development. Another inference which may fairly be drawn is, that upon photographs of spiral nebulæ, and of globular clusters, we shall first find conclusive evidence of structural changes taking place, together with the import of such changes; though a period of four years is too short to enable us to prove that any obvious change has taken place in the spiral nebula M. 33 *Trianguli*.

On the Proper Motion of Lacaille, 4336, Mag. 5·5.

By R. T. A. Innes.

This star (R.A. $10^h\ 26^m\ 42^s$, Dec. $-53^\circ\ 6'$, 1880) with a 8·2 mag. companion (Cordoba Zones 10^h, 1929) makes the pair *h* 4329 of which I have found the following measures:

1837·1	$17^\circ{\cdot}1$	$17''{\cdot}5$	*h*	2 nights
1846·3	29·6	17·5	Jacob	
1873·2	63·7	21·9	Russell	1 night
1881·5	71·7	23·4	Hargrave	„

This star is sometimes called *Y Velorum*: it is a white star, the *comes* being red, according to *h* and Russell.

The change of position is well accounted for by applying to Lac. 4336 a proper motion of $0''{\cdot}44$ towards $297^\circ{\cdot}5$, or R.A. $-0^s{\cdot}043$ Dec. $+0''{\cdot}203$. This proper motion is not too inconsistent with the positions I have at hand, viz. the B.A.C., the A.G.C., and Stone's Cape Catalogue.

It has occurred to me that, if Mr. Stone were asked, he would kindly supplement my remarks with a comparison of the meridian observations, which might be somewhat reconciled with each other now that we have an independent determination of the proper motion.

Sydney: 1895 *November* 1.

Mr Innes's conclusion that the alterations in position angle and distance of these two stars are principally due to the proper motions of the star, Lacaille 4336, appears to me quite correct. I find on reference to my manuscript of proper motions that the principal star has proper motions of about $-0^s{\cdot}051$ in R.A. and $-0''{\cdot}16$ in N.P.D. The first depends entirely upon a comparison between Taylor and Stone, and probably requires a correction of about $+0^s{\cdot}005$ on account of systematic errors of Taylor's R.A. The proper motion in N.P.D. depends on comparisons between Stone and four other catalogues.—E. J. Stone.

Setting Apparatus for a Transit Circle. By W. E. Cooke, M.A.

(Communicated by the Secretaries.)

I beg to offer the following suggestions for an apparatus to facilitate setting a transit circle in Z D. I cannot attempt to enter into details, for so much depends upon the shape of the instrument and the class of work for which settings are required. But the general idea will be readily grasped by the aid of figures 1 and 2, where 1 represents the apparatus viewed from north or south, 2 from east or west. C is a light flanged or grooved circle attached to the axis, parallel to and about the same size as the graduated circle. Attached to the rim is a non-extensible cord, the end hanging vertically and carrying a pointer P. The diagram shows P as a framework, across the middle of which a horizontal thread is stretched, capable of a small vertical adjustment by means of a rackwork.

Fig. 1. Fig. 2.

As the telescope is revolved, P will move up or down, and its vertical height above any arbitrary fixed point will give an indication of the declination of the star towards which the telescope is directed.

R is a vertical cylinder which rotates by clockwork once in twenty-four sidereal hours, and can be readily adjusted on its

revolving spindle if necessary. Upon its surface a sheet of paper is stretched, on which lines are drawn to represent R.A. and Dec. The R.A. lines are obtained by dividing the circumference of the cylinder into 24 hours &c., and the distance separating the successive lines of declination is obtained from the vertical moment of P. After drawing these lines, all clock stars and all those stars included in the current working list can be plotted and the cylinder mounted. It is adjusted in the first place so that the sidereal time at the instant of mounting corresponds to the same moment of R.A. on the cylinder opposite the centre of P. The apparatus is now ready for use, the only attention required being the occasional winding up of the clockwork.

The rotation of R will bring each star in succession opposite the middle of P (or rather opposite a vertical line through this point) at the moment the real object crosses the meridian, and by moving the telescope until the cross hair of P cuts the picture of the star, we shall bring the object itself into the field of view.

The observer therefore will not require either a sidereal clock or a star list for setting purposes. Standing in front of the telescope he sees by a glance at the cylinder what stars are approaching the meridian, and he sets for any particular one by simply revolving the instrument until the cross hair of P bisects the picture of the selected object.

Adelaide Observatory:
1895 *September* 10.

The Radiant Point of the October Meteors (Orionids). By W. F. Denning.

So many meteor-showers are now known or suspected, and the great proportion of them are of such feeble and uncertain character, that it seems scarcely desirable to multiply them by further observation. Instead of searching for new and feeble systems, the meteor observer would perhaps be better engaged in directing attention to the rich periodical streams, and investigating their peculiarities with more closeness than has been done hitherto.

It is certain that the features of moving and stationary radiants cannot be well examined in regard to the very feeble showers, but that we must select prominent displays, and such as are pretty durable, like the *Perseids* and *Orionids*. Streams of this character are sufficiently rich and prolonged to be traced very satisfactorily on many successive nights, whereas the minor systems are so tenuous, and apparently so intermittent, that the observer finds it extremely difficult to gather sufficient

materials to test their visible behaviour. The *Perseids* have already been found to form a radiant subject to a very obvious and rapid motion to the eastwards amongst the stars (*Monthly Notices*, xxxviii. p. 308, and xlv. p. 97–8). But the *Orionids* appear to be typical of a shower having a fixed radiant during the whole time of its presentation (*Monthly Notices*, l. p. 415). I have watched the radiant closely without ever being able to detect the slightest change in its apparent place. The shower commences on October 8, possibly on October 5, and continues until the 29th, but I have only seen it sufficiently well to determine good radiants from October 8 to 24. I have re-examined my observations of this shower in and since 1874, and reprojected many of the meteors registered from it. After correcting some clerical and printer's errors in previously published lists my radiants are as follows :—

Date.			Radiant.	Meteors.
			° °	
1877	October	8	91 + 13½	5
1887		12–13	91 + 17	4
1879–87		14	91 + 15	6
1879		15	93 + 17	16
1887		15	91 + 16	17
1877		16	91 + 15	15
1877		17	93 + 14	33
1884, &c.		17	92 + 14	4
1887		17	90 + 15	3
1877		18	92 + 15	9
1887		19	90½ + 15½	10
1877 & 90		19	90 + 15	4
1876		17–21	88 + 17	8
1874		18–21	90 + 17	8
1879		20	93 + 15	21
1887		20	90 + 14½	22
1887		21	92 + 14	23
1878		22	91 + 15	11
1887		24	91 + 16	9
1874–90	October	8–24	91·1 + 15·3 (mean of 19)	228

Many other observers have seen this fine shower and accurately determined its radiant. I have selected the following results as undoubtedly representing the best observations :—

Date.			Radiant.	Meteors.	
1869	Oct.	5–6	91° + 9°	8	Tupman, G. L.
1869		10	90 + 12	...	Tupman, G. L.
1893		10	91 + 16	8	Corder, H.
1869		12	89 + 16½	5	Tupman, G. L.
1869		13	88 + 14	12	Tupman, G. L.
1888		13	90 + 13½	6	Booth, D.
1869		15–16	89 + 16	15	Tupman, G. L.
1895		16	91 + 15	6	Corder, H.
1895		16–22	89 + 13	10	Blakeley, E. R.
1876–9		16–22	90 + 14	...	Corder, H.
1869		17	91 + 18	...	Tupman, G. L.
1868		17–18	90 + 17	32	Backhouse, T. W.
1892		17–23	87 + 18	9	Corder, H.
1892		17–29	92 + 15	...	Milligan, W. H.
...		17–31	93 + 18	5	Heis, E.
...		17–Nov. 13	90 + 15	...	Greg and Herschel
1864		18	90 + 16	14	Herschel, A. S.
1867		18–20	90 + 15	12	Herschel, A. S.
1863		18–21	94 + 15	...	Schmidt, J. F. J.
1879		19	92 + 15	8	Sawyer, E. F.
1868		19–21	88 + 14	14	Wood, W. H.
1868		19–22	92 + 18	...	Schmidt, J. F. J.
1867		19-27	92 + 17	...	Schmidt, J. F. J.
1887		20	91½ + 15	10	Booth, D.
1865		20	90 + 15	19	Herschel, A. S.
1868		20–31	92 + 18	64	Zezioli and Weiss (reduced by Denning)
1868		21	93 + 15	31	Zezioli, G. (reduced by Schiaparelli)
1868		21	95 + 18	29	Zezioli, G. (reduced by Denning)
1848–68		21	93 + 18	36	Gruber, L.
1892		...	90 + 17	...	Backhouse, T. W.
1848–95	Oct.	5–Nov. 13	90·8 + 15·5 (mean of 30)		

The mean position of these is very nearly identical with the mean derived from observations at Bristol. In the foregoing table I have included Lieut.-Col. Tupman's observation of 1869 October 5–6, though it is unusually early, and though the radiant is 6° south of the proper place. The shower, however, has been so distinctly visible on October 10 to Lieut.-Col. Tupman

and Mr. Corder, while I have myself remarked traces of it on October 8, that it seems fair to assume its visible opening for October 5.

It is evident that if the radiant of the *Orionids* moved eastwards at the rate of 1° per day (as suggested for ring-formed meteor-systems by the late Dr. Kleiber), its displacement would have been readily apparent. For example, had the radiant occupied the following places the observations must have shown it in the most conclusive manner:—

October	12	85° + 15°
	18	91 + 15
	24	97 + 15

for a difference of 12° in the position is very large, and could not possibly have escaped detection. I believe my own determinations of radiants are within 2° of probable error.

The motion, if any, of the radiant would be in increasing R.A., as above; but apart from the test afforded by the comparison of radiants, let us examine the point by selecting such meteor paths (observed at Bristol) as were not far from their centre, and had motions chiefly in declination. It will be seen by the following paths of *Orionids*, recorded from October 12 to 24, that they indicate no displacement whatever in the right ascension of the radiant.

				Path.	
				From.	To.
		h m	Mag.	° °	° °
1887	October 12	12 19	4	90 +25	89 +29½
1887	15	14 33	3	91 +25	91 +29
1877	16	12 22	3	90 +43	88 +63
1877	16	12 39	1	91 + 8	91 + 5
1877	16	13 54	4	94 + 2	96 − 4
1877	17	14 20	5	91 +20	90 +25
1877	17	14 31	3	95 − 6	96 −15
1877	17	14 37	4	91 − 3	90 −10
1877	17	15 2	3	86 ± 0	83 − 7
1895	17	16 5	4	88 − 2	87 − 5
1877	18	17 0	4	86 +10	83 + 7
1874	19	11 25	4	84 +13	77 + 9
1887	19	13 9	2	91½ +33	92 +38½
1879	20	8 32	1	86½ +22	79 +29½
1887	20	11 45	4	83 +25	79 +29
1879	20	11 59	4	94½ +22	96½ +25
1887	20	15 5	4	90 +66	90 +74
1887	21	12 5	1	86 + 5½	83 + 1½
1887	21	12 35	3	86½ +20	84 +22½
1887	24	12 18	4	91½ +35½	92 +40½
1887	24	12 30	4	95½ +36	97 +43

The star ν *Orionis* (mag. $4\frac{1}{2}$) is close to the radiant of this shower, as the following comparison will show :—

Place of radiant from 19 observations at Bristol	$91°.1 + 15°.3$
Place of radiant from 30 observations by various observers ...	$90.8 + 15.5$
Place of ν *Orionis* (1896)	$90.4 + 14.8$

A careful comparison of all the radiants given in the two lists will not reveal any indication of displacement. Some of the positions included in the second list are not, however, of much utility in their bearing on this feature, as they depend upon several nights of observation. Between October 5 and 29 the radiant retains a constant position about 1° N.E. of ν *Orionis*. In confirmation of its place near this star Professor Herschel writes : "I had always found the radiant so exactly at ν *Orionis* or so very near to it that that star became synonymous to me with an R.A. and declination place for the shower-centre, and I used it thus, in October 1867, as a just equivalent to a coordinate position."

There are several other showers from the region of *Orion* in October. There is one at $86° + 8°$ (near α *Orionis*), another at $89° + 20°$ (near χ *Orionis*), very definitely visible in September as well as in October, a third at $97 + 15$ (near γ *Geminorum*), and a fourth at $107° + 12°$ (near β *Canis Minoris*). The one near γ *Geminorum* has been detected by several observers independently, as follows :—

Date.		Radiant.	Meteors.	
1869	Oct. 14	$97° + 10°$	9	Tupman
1879	20	$97 + 11$	5	Denning
1892	17–23	$96 + 18$, $99 + 15$, $98 + 11$	22	Corder { apparently a uniform radiant
1871	21	$98 + 16$	6	{ Miss I. Herschel, Miss J. Herschel
1868	21	$96 + 13$	...	Zezioli
1871	21–23	$97 + 15$	13	Backhouse
1875	21–23	$96 + 17$	9	Backhouse
1893	22	$97 + 19$	4	Corder
1895	23–27	$97 + 17\frac{1}{2}$	15	Corder
1892	...	$98 + 18$	5	Backhouse
1894	Oct.–Nov.	$97 + 18$	5	Corder

The mean is at $97°.1 + 15°.2$, and 6° E. of the *Orionid* centre. The radiant in *Canis Minor* (N.W. borders) is also very distinct,

and about 10° E. of the γ *Geminids*. The following are five observations of it:—

Date.		Radiant.	Meteors.	
		° °		
1869	Oct. 8	107 + 12	...	Tupman
1877	8–19	103 + 12	22	Denning
1879	15–20	106 + 12	5	Denning
	...	110 + 14	9	Corder
	18–27	108 + 12	...	Schmidt

The mean is at 106°·8 + 12°·4 and about 5° N.W. of β *Canis Minoris*.

There is another active shower at this epoch about 10° N. of this and near δ *Geminorum*. These several displays require further investigation, with special regard to the positions of their radiants. As to the γ *Geminids* (97° + 15°) I cannot quite understand this shower, as I only noticed it on one occasion (in 1879) and then from a position 4° S. of the mean place of the radiant as given by other observers. It is highly probable that many of the true *Orionids* are implicated in producing it, but it cannot be altogether set aside, the observations being too plentiful and corroborating one another in a way not to be disregarded. γ *Geminorum*, which is close to this radiant, is the brightest star a little east of the *Orionid* centre, and we should naturally expect that, in some cases, the observed tracks of *Orionids* would be estimated as directed precisely from that star, though really emanating from a point 6° west. This might sometimes have led the true *Orionid* radiant to be placed a little too far east and near γ *Geminorum*, but the point is one to be cleared up by further observations.

Bristol: 1895 *October* 30.

Observations of Perrine's Comet (c 1895) *made with the Altazimuth at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

These observations were made and reduced in a similar manner to those of the Moon with this instrument—viz. transits were taken by the galvanic method over the vertical and horizontal wires for observations of azimuth and zenith distance respectively, and the microscopes and levels were read. A double observation of *Regulus* was obtained on each day to determine the instrumental adjustments.

The following are the individual observations of azimuth and zenith distance:—

G.M.T.	Observed Azimuth.	G.M.T.	Observed Zenith Dist.
d h m s	° ′ ″	d h m s	° ′ ″
1895 Dec. 6 18 7 8	304 19 0·7	Dec. 6 18 23 43	82 1 56·0
18 21 5	307 11 47·1	18 36 56	80 27 14·1
18 33 34	309 48 41·4	18 49 41	78 59 41·8
7 18 48 27	312 39 54·8	7 18 50 36	80 55 55·3

The above mean times are uncorrected for aberration. The observations are corrected for collimation, level, refraction, and parallax. In computing the latter, log Δ has been taken as 9·9680 on December 6, and 9·9547 on December 7, these values being interpolated from Professor Lamp's ephemeris in *Astr. Nachr.* 3,320, the corrections applied being 9″·4, 9″·4, 9″·3, 9″·7 respectively.

The aberration times were computed with the same value of log Δ, and found to be $7^m\ 42^s$ and $7^m\ 28^s$ on the two days. The tabular R.A. and N.P.D. were computed from Professor Lamp's ephemeris with third differences, after applying these corrections to the above mean times. The tabular azimuths and zenith distances were then computed for each observation, and the deduced apparent errors of the tabular places are as follows:—

G.M.T.	Tabular Azimuth—Observed Azimuth.	G.M.T.	Tabular Z.D.—Observed Z.D.
d h m s	″	d h m s	″
1895 Dec. 6 18 7 8	−40·3	Dec. 6 18 23 43	+66·7
18 21 5	−41·2	18 36 56	+71·0
18 33 34	−38·0	18 49 41	+65·0
7 18 48 27	−61·1	7 18 50 36	+98·7

The following errors of tabular R.A. and N.P.D. were then deduced:—

	Error of Tab. R.A.	Error of Tab. N.P.D.
	s	″
Dec. 6	+4·78	+38·5
7	+7·00	+57·0

Now the tabular R.A. and N.P.D. at the means of the times are as follows:—

G.M.T. (Uncorrected for Aberrn.)	Tab. R.A.	Tab. N.P.D.
d h m s	h m s	° ′ ″
1895 Dec. 6 18 28 41	15 4 32·27	105 37 43·7
7 18 49 31	15 13 52·94	107 17 55·0

Whence are deduced the following observed R.A. and N.P.D.:—

G.M.T. (Uncorrected for Aberrn.)	Apparent R.A.	Apparent N.P.D.
d h m s.	h m s	° ′ ″
Dec. 6 18 28 41	15 4 27·49	105 37 5·2
7 18 49 31	15 13 45·94	107 16 58·0

The comet was very bright, and was observed in an illuminated field. On December 6 a distinct tail was seen pointing westward from the nucleus. The comet was looked for on several other mornings, but, owing to clouds, no other observations were obtained.

The observers on December 6 and 7 were Mr. Crommelin and Mr. Hollis respectively.

Royal Observatory, Greenwich:
1895 *December* 13.

Observations of Comets Encke, 1894, and Swift, 1895 August 20, at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observations were made with the 10-inch Barclay Equatorial, using the ring-micrometer, with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	Comet *minus* Star N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
					Comet Encke, 1894.								
1895.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Jan. 18	5 47 32	1 34 0	W.	−0 21·83	+2 14·6	11	21 55 57·92	+0·43	9·4733	91 40 21·5	10·2	0·8447	(*a*)
21	6 10 36	2 8 58	W.	−1 49·77	+2 34·9	3	21 47 18·24	+0·51	9·5220	93 32 16·5	10·7	0·8471	(*b*)
23	5 58 8	2 4 21	R.	−2 0·30	−0 4·4	4	21 39 54·13	+0·52	9·5254	95 5 41·2	11·0	0·8497	(*c*)
25	5 52 41	2 6 47	R.	−3 48·23	+6 3·5	3	21 30 59·01	+0·55	9·5357	96 56 53·3	11·3	0·8508	(*d*)
					Comet Swift, 1895 August 20.								
Aug. 24	12 5 15	22 12 15	R.	−6 20·85	+0 59·1	6	0 36 28·91	−0·40	9·3346	84 8 52·7	11·9	0·8074	(*e*)
24	12 14 1	22 21 3	R.	−7 47·46	−0 39·9	5	0 36 29·97	−0·38	9·3108	84 8 53·8	11·8	0·8064	(*f*)
28	11 21 56	21 44 35	R.	+0 19·16	+5 55·1	7	0 45 7·92	−0·49	9·4154	83 56 16·7	12·2	0·8001	(*g*)
28	12 8 36	22 31 22	R.	−2 5·98	+2 25·1	7	0 45 11·72	−0·38	9·3064	83 56 21·4	12·0	0·8050	(*h*)
Sept. 18	11 2 16	22 47 39	R.	+1 53·11	+0 24·3	8	1 16 13·79	−0·82	9·3429	84 23 23·3	23·9	0·8090	(*i*)
20	11 29 21	23 22 42	R.	−0 15·69	+7 32·1	17	1 17 52·84	−0·65	9·2472	84 32 4·8	23·6	0·8073	(*j*)
25	10 48 10	23 1 7	R.	+0 15·01	+0 43·0	13	1 21 11·45	−0·56	9·3230	84 54 21·9	17·2	·8114	(*k*)

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
1895.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
27	12 32 0	0 53 7	R.	+2 29·55	−0 46·4	6	1 22 14·88	−0·20	8·8916	85 4 18·3	16·7	0·8074	(*l*)
Oct. 17	9 18 50	22 58 16	R.	−0 38·87	−4 58·6	6	1 26 39·97	−0·47	9·3438	86 21 42·2	14·0	0·8205	(*m*)
17	9 41 27	23 20 57	R.	−0 28·29	+4 57·9	6	1 26 40·44	−0·40	9·2805	86 21 54·2	13·9	0·8191	(*n*)
24	10 21 20	0 28 33	R.	−1 27·77	+6 35·9	8	1 27 23·39	−0·18	8·9678	86 33 8·2	12·7	0·8177	(*o*)

Observers' Remarks.

(*a*) The comet was faint when first observed owing to twilight. There is no tail, but a coma with brightening slightly following the centre of coma. The noises from bells, trains, and street are troublesome. (*b*) The comet is brighter than on January 18; a nucleus can be seen by gazing some time, but was of little use in observing: as before, the centre of the patch was taken. The objects were very low, and definition poor. Heavy clouds, with occasional breaks, drifted over during the observations of this evening. The above set was obtained in a break, and through trees. (*c*) Wind gusty this evening. The nucleus of comet is a diffused disc of the 9 or 10 magnitude, and follows the centre of the nebulosity. The image of the star is bright, but not well defined at times; objects low. (*d*) Difficult observations, some through trees. Comet, which is visible in strong twilight, is a diffused mass; centre observed. (*e* and *f*) The diameter of the coma surrounding the condensation is, approximately, 2′; it is an extremely faint, nebulous object. Observations difficult; guesswork at times. (*g* and *h*) There is no apparent change in the comet since August 24; the nebulous haze, with slight condensation, is extremely faint. Observations made with difficulty. (*i*) The faint nucleus is enveloped in a feeble coma which can be traced over a diameter of 3′. Sky unusually clear till midnight. (*j*) Comet extremely feeble, with a condensation. During the earlier comparisons to-night a star of about the same brightness as the nucleus (14 mag.) preceded, very closely, within the coma: this increased the difficulty of observation. (*k*) The star selected for comparison (mag. 9½) is the brightest in the vicinity, but it is inconveniently close to the comet. There is no appreciable change in the form of the comet's coma and condensation; but the comet seems brighter than on any previous night. The sky is very clear above the ground fog. (*l*) The presence of a bright star in the field of view increased the difficulty of seeing the comet, which was very faint. (*m* and *n*) A star (mag. 10½ or 11) followed the comet, say 3ˢ; the close proximity of this star made the observation very difficult, the comet being sometimes lost in the glare of the star. (*o*) The comet is a small faint haze without any perceptible nucleus; the centre observed as nearly as possible. Very difficult observations. Sky very clear.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson.

Assumed Places of Comparison Stars.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	21 56 20·55	−0·80	91 38 0·0	+ 6·9	Gould 30140.
(*b*)	21 49 8·81	−0·80	93 29 33·8	+ 7·7	Gould 29971.
(*c*)	21 41 55·23	−0·80	95 5 37·3	+ 8·3	Radcliffe, 1890, 5875.
(*d*)	21 34 48·03	−0·79	96 50 41·0	+ 8·8	Mean of Lamont 29127 and Schjellerup 8788.
(*e*)	0 42 46·50	+3·26	84 8 16·1	−22·5	Radcliffe transit-circle observations, 1895.
(*f*)	0 44 14·17	+3·26	84 9 56·3	−22·5	Radcliffe transit-circle observations, 1895.
(*g*)	0 44 45·42	+3·34	83 50 44·7	−23·1	Radcliffe transit-circle observations, 1895.
(*h*)	0 47 14·37	+3·33	83 54 19·4	−23·1	Radcliffe transit-circle observations, 1895.
(*i*)	1 14 17·03	+3·65	84 23 24·8	−25·9	Radcliffe transit-circle observations, 1895.
(*j*)	1 18 4·80	+3·73	84 24 58·8	−26·1	Radcliffe transit-circle observation, 1895.
(*k*)	1 20 52·69	+3·75	84 54 5·4	−26·5	Radcliffe transit-circle observations, 1895.
(*l*)	1 19 41·55	+3·78	85 5 31·3	−26·6	Albany, A.G., 392.
(*m*)	1 27 14·86	+3·98	86 27 8·1	−27·3	Albany, A.G., 424.
(*n*)	1 27 4·75	+3·98	86 17 23·6	−27·3	Albany, A.G., 423.
(*o*)	1 28 47·13	+4·03	86 26 59·6	−27·3	Albany, A.G., 440.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken, for (*a*), (*b*), (*c*), (*d*) from the *Bulletin de l'Académie Impériale des Sciences de St.-Pétersbourg*, 1894 Novembre; for (*e*), (*f*), (*g*), (*h*) from No. 3,308, for (*i*), (*j*) from No. 3,309, and for (*k*), (*l*), (*m*), (*n*), (*o*) from No. 3,310 of the *Astronomische Nachrichten*. The values of Δ given in these ephemerides for Comet Swift are discordant.

Radcliffe Observatory, Oxford: 1895 *December* 12.

Errata in Monthly Notices, Vol. LVI. No. 1.

Page 36, line 28, *for* them *read* then.
" 38, line 3, *for* 1906 *read* 1900.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. JANUARY 10, 1896. No. 3

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

Hugh Lancelot Aldis, 67 Dieppe Street, West Kensington, W.;
William Ernest Cooke, M.A., First Assistant, Observatory, Adelaide, South Australia;
Alpin G. Fowler, M.Inst.C.E., 1 Cambridge Road, Norbiton;
David Edward Hadden, Alta, Buena Vista Co., Iowa, U.S.A.;
Rev. Robert Killip, Sale, near Manchester;
George Handley Knibbs, University, Sydney, New South Wales, Australia;
Frederick William McCarthy, 20 Chepstow Place, Bayswater, W.;
Charles J. Merfield, Department of Public Works, Sydney, New South Wales, Australia;
Captain Hugh Griffith Quirk, Baymount, Vico Road, Dalkey, co. Dublin,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Thomas Edward Knightley, Architect, Clive House, Tulse Hill, S.W. (proposed by Edward Carpmael);
James Cavan, M.A., Eaton Mascott Hall, Shrewsbury (proposed by A. C. D. Crommelin).

Seventy-seven presents were announced as having been received since the last meeting, including amongst others :—

A. Fowler, Popular Telescopic Astronomy, presented by the publishers ; photographic enlargements from a negative of the Moon by MM. Lœwy and Puiseux, presented by Dr. L. Weinek ; lantern slides from Professor Keeler's drawings of *Mars*, 1892, presented by Mr. Newbegin.

Note on the Indexing of Scientific Papers. By H. Seward, B.A.

In the present condition of scientific periodical literature the question of a subject-matter index is one of very great importance, and the necessity of some such work is yearly becoming more evident. As one who has had a large experience in indexing, especially in indexing of a scientific character, I venture to offer a few remarks on the subject, in accordance with the suggestion of the Secretaries in the last *Monthly Notices*.

First of all it is to be pointed out that a good index can only be made by an expert. It might be supposed that any person of ordinary literary or scientific attainments could make a satisfactory index, but everyone who has studied the subject knows that this view is entirely erroneous. Careful training in classification is absolutely necessary, and this is in most cases the work of years. From this it follows that the system (of indexing by authors), suggested by the Secretaries of the Royal Society, and tentatively adopted by our own Secretaries, can only be regarded as a very temporary one, and that it is one which is certain to break down in practice. The cause of the inevitable failure of this system is not so much the fact that authors often take a view of the importance of their own work which is not shared by their readers, but lies in the impossibility of obtaining uniformity by this method. Thus, to take a simple case : suppose papers on a total eclipse of the Moon are to be indexed, it will be found that these will be variously indexed under the words, "Total," "Eclipse," "Moon," "Lunar," by different authors (without counting such probable entries as "Colour of Eclipsed Moon," "Red Colour of Eclipsed Moon," "Earth's Shadow, Radius of," "Penumbra," &c., &c.), and the unfortunate compilers of an index will have to wade through masses of useless verbiage, meanwhile running the risk of missing something of importance. It can easily be seen that subject matter of a more complicated description, such as, say, "Measurements of the Wave Lengths of the principal lines in the Spectrum of *Nova Aurigæ* as determined by Photography," will lead us at once to hopeless confusion. We are thus drawn to the conclusion, which is, in fact, well known to trained indexers, that the first essential of an index is uniformity ; the same subject matter must always be

indexed in the same place. What this place is, is comparatively a matter of small importance. For instance, it matters little whether we index "Heliometers" under "Telescopes" or under "Micrometers," provided that all heliometers are indexed under one or the other heading, and not some in one place and some in another.

The next desideratum is to ensure as far as possible that one thing should be indexed in one place, and one place only. The object of this rule is to obtain the maximum of simplicity in the index. Unfortunately it is impossible to carry this out rigidly. It is obvious that such subject matter as "Photographs of Nebulæ" is of interest under both "Photography" and "Nebulæ," and that there will thus be many topics which will require indexing in more than one place. By means of a judicious system of "cross references," much of this repetition can be dispensed with, but there will always be a residuum of certain items which will need double or multiple indexing.

In order still further to obtain uniformity and simplicity, it will generally be found that a small number of indexers is more useful than a larger one. But be the number large or small, when once the general style of the index has been determined, the best practical plan is to draw up what may be called a skeleton index, *i.e.*, a list of headings and sub-headings to be used by the indexers, without any entries after the headings or sub-headings. This skeleton or "Key" index will at first be incomplete, and must be added to as occasion arises, care being always taken not to add anything which will be inconsistent with, or overlap, previously existing items. For this purpose the utmost possible accuracy and definiteness of statement is requisite. The wording of each heading and sub-heading must receive the most careful consideration; all ambiguous terms (such as "&c.") must be discarded; and when once a term has been decided on, no apparently synonymous one must on any account be allowed to take its place in the same heading or in related headings. One thing must always be called by one name, and one only. Besides the headings and sub-headings our "Key" must contain such cross references as are found necessary or desirable, though it is always well to cut down the number of these as far as possible, and also directions as to what subject matter is to be repeated under other headings. No radical or systematic alteration in this "Key" can generally be allowed unless under most exceptional circumstances. Of course with the progress of the science small alterations will frequently become desirable, but even these should be made very sparingly and only under extreme pressure.

The first and most useful practical step will therefore be the preparation of this skeleton index, for when once a working index has thus been obtained, three-fourths of the difficulties of indexing will disappear; it will be found that by far the greater number of items to be indexed will range themselves automatically under one or more headings or sub-headings. A few

cases only will remain which will require special treatment, usually by the addition of further cross references or new headings or sub-headings to the skeleton index. The utmost care must be bestowed on this "Key," as the facility in dealing with subsequent cases which is thus obtained will more than counterbalance a large amount of trouble in the original preparation. It would appear to be desirable to entrust the compilation of such a "Key" to a small committee, composed of men each with a special knowledge of some particular branch of astronomy, and all with sufficient enthusiasm for the science to take an interest in the little-regarded details of indexing. Such a committee could, with a comparatively small amount of work, achieve results the benefits of which would be felt by our science for many years to come.

We have only considered the question of the indexing of scientific papers in a general way; many of our conclusions may seem quite obvious, and others may seem to be based on unimportant details. The subject of indexing is so little understood, except by those who have had occasion to study it closely, that the importance of the considerations here advanced will probably not at first be admitted, but a very short practical experience will be sufficient to show the immense importance of the two points which we have laid down as essential, viz. *uniformity* and *simplicity*, and in order to carry out these essentials the plan of a skeleton index seems to be the most convenient and feasible one that can be adopted. The actual method of preparation of such an index is, of course, a matter for discussion, as to which many opinions may easily be maintained.

Until such a working index is, at any rate, in course of preparation, it would be well to defer further discussion with special reference to the science of astronomy; but it may perhaps be here noticed that it is very doubtful whether any index on such subjects as measurements of double stars, or observations of variable stars, can conveniently take the place of compiled catalogues such as we find in the published works of Burnham and others.

Note on a Crayon Drawing of the Moon by John Russell, R.A., at the Radcliffe Observatory, Oxford. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

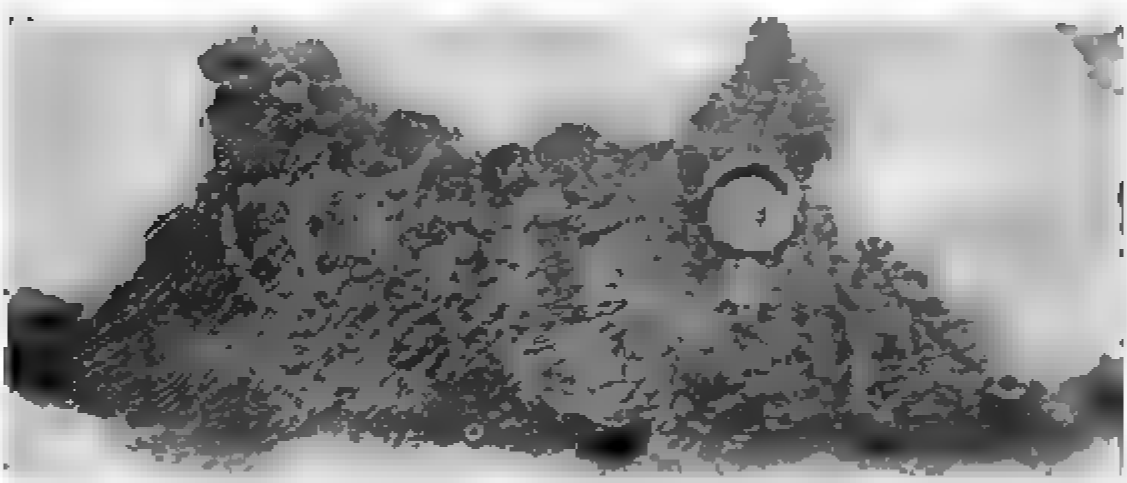
There is at the Radcliffe Observatory a crayon drawing of the Moon, made by the celebrated artist John Russell, R.A.

The drawing is 4 ft. 11 in. by 5 ft., and bears the date 1795. It is on paper stretched on canvas, and the paper is composed of sections carefully seamed together; the chief seam being across the centre. The surface is not *perfectly* flat.

Mr. Russell died in 1806 May; but the drawing did not

come into the possession of the Radcliffe Trustees until 1824 December.

When first received at Oxford the drawing was found to have been rather seriously damaged by wet on the journey. But Miss Russell, the artist's daughter—who was herself an artist, and trained in her father's methods—most kindly offered her assistance to restore the picture, and it was forwarded to her for this purpose. The drawing was returned to the Observatory on 1826 May 8, and it has remained there ever since.



Photographic reproduction of one of Russell's pencil drawings of Copernicus and its neighbourhood.

The crater Copernicus comes on the damaged portion of the drawing, and it would appear that Miss Russell, in her attempts at restoration, must have altered this part of the drawing, as it differs considerably from the original drawings of Mr. Russell of this crater, a copy of one of which is given above.

It appears that Mr. Russell's attention was first drawn to the desirability of the execution of drawings of the Moon by some skilled artist by Sir Joseph Banks, P.R.S. Mr. Russell was supplied with a six-inch reflector by Dr. Herschel, and he devoted to the work all the nights suitable for such work, which he could possibly spare, for nearly eighteen years.

A large number of detailed pencil drawings of different portions of the Moon's surface, made by Mr. Russell, are also in the possession of the Radcliffe Trustees; and many of them appear to me of an extremely interesting character.

The wet stains on the large crayon drawing, already alluded to, are principally on the blue background of the sky. They have always been visible since I have been at Oxford; but I have

thought that within the last year or two they have become more pronounced, and that there were clear indications of mildew. I have, therefore, dismounted the drawing, and had photographs of it taken: (1) in the state it was found before any attempts were made to remove the mildew or dust; and (2) after the crayon drawing had been cleaned as far as I felt certain this could be carried out without damage.

These photographs have been taken by Mr. McClellan, an assistant at the Observatory.

I have thought that these photographs might be of some interest to the Fellows, as showing the general appearances of the Moon as it presented itself to the eye and was delineated by the hand of a skilled artist about a hundred years ago.

So far as I can judge, there are, as might be expected, during these hundred years, no distinct indications of change on the lunar surface.

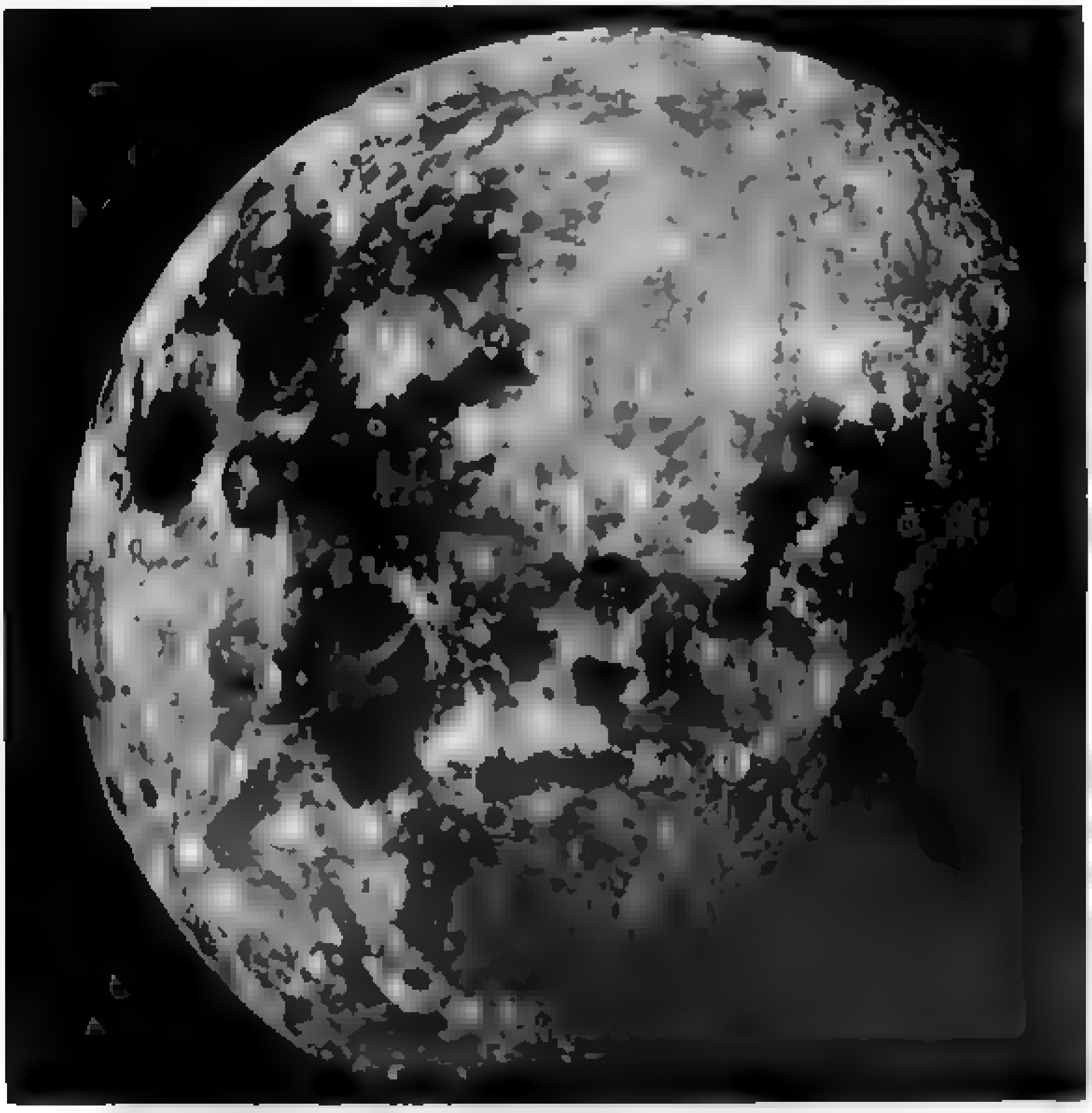
I have appended a letter from Mr. Russell to Dr. Hornsby, which appears to me interesting, as giving some account of the views of the artist on such work. The original spelling has been retained.

Sir

I thank you for the fresh instance of your condescending goodnefs, in the Answer I am favor'd with to my last Letter, and your umerited willingnefs to give me afsistance; which induces me to trouble you once more to read a Letter from me, containing my ardent Request to be indulged with a sight of the Drawing of Tycho you are so good to offer after Biachini, as I have never met with the Book you mention, which contains this and the Representation of other Spots in the Moon, with which I am somewhat acquainted as I have paid particular attention to these Spots, when the line of illumination falls directly upon them, by which I may receive considerable hints, and be enabled to determine, how much superior utility there is, in a Telescope of power considerably beyond the one I use, in deliniating the Moon; of which I am not so fully convinced, by the Print which Mons[r] le Comte de Cafsini when in England inform'd me was drawn by means of the large Telescope in the Observatory at Paris.

I am greatly obliged by your observations respecting the Polar and Equatorial Diameters of the Moon, what I meant by the line of illustration, was the edge or boundary of illumination directly from the Sun; and I was fearfull when I exprefs'd a considerable difference between the Polar and Equatorial Diameters, I might be supposed to have made the measure before the whole Moon was compleatly illuminated, therefore I exprefs'd myself as attending to the real Margin of the Moon in an early state, one side illuminated directly by the Sun, and the other by the Earths Reflection.

Pardon Sir my want of clearnefs.



Woodburytype *E. & S.*

PHOTOGRAPH OF RUSSELL'S CRAYON DRAWING OF THE MOON, DATED 1795, AT THE RADCLIFFE OBSERVATORY, OXFORD.

In answer to your question respecting my Work, "If it be only one large Map," I cannot help troubling you with the following. About twenty-five years since, I first saw the Moon through a Telescope, which I now recollect must have been about two Day after the first Quarter; you will conclude how much struck a young Man conversant with Light, and Shade, must be with the Moon in this state; especially, as I was not taught to expect such clearnefs and exprefsion, as is to be found near and upon the indented Edge; a few Days after I made a small Drawing, but the Moon being at the Full, I was not struck in the same manner, and I made no more attempts, till an accidental pofsefsion of a powerful Glafs awakened my attention to this beautiful Object once more, and for several years I have lost few opportunities when the Atmosphere has exhibited the Object of my study and imitation.

Before I began to deliniate the Moon I never saw any other representation, but the very inferior Prints to be met with in common Dictionarys, such unsatisfactory imitations, both as to incorrectnefs of Form and Effect, led me to conclude I could produce a Drawing in some measure corresponding to the Feelings I had upon the first sight of the gibbous Moon through a Telescope; that might give some pleasure to those who had view'd that Object attentively, for as to pecuniary profit, it was quite out of the question. After some succefsful attempts I met with two Maps in a Work by Joh^{e} Bapt^{a} Homanno, Norinbergæ, one was a copy of the full Moon by Hevelius the other after Ricciolus: upon the sight of these, I thought it was needlefs to prosecute the subject, they having more correctnefs in the parts than what I thought had been executed; but observing how little the Effect was produced (to speak as a Painter) I continued to divert myself. About a year after I met with the folio Volume of Hevelius and was again at a stand, but by this time I found that my experience had not only made me more expert in imitating what I saw, but my powers of discernment and discrimination were considerably improved, and I persued the subject with redoubled ardour, and I scarce lost a moment when the Moon was above the Horizon. About a year and half since I heard of the print after the Drawing by the late celebrated Astronomer Cafsini was publish'd in Paris. As I cou'd not but suppose the Work of so eminent a Profefsor with the powerful Telescopes of the French Observatory must pofsefs very superior excellence; who knowing what had been already done, could not employ himself without attempting very considerable improvements, however I still continued my persuit and employ'd a correspondent to procure me one of the Prints, but without succefs. On my return to London Mons^{r} le Comte de Cafsini being in Town, who having heard of my Attempt favord me with a call, and indulged me with a sight of his celebrated Grand-Fathers Moon, in which I found my expectations were not disappointed, and that this Print as far exceeds all others which I

had seen in correctnefs and intelligence as it does in magnitude which is very considerable. But as you Sir would inform me, the Moon requires much attention to be well understood, being composed of so many parts, of different characters, so much similitude in each Clafs of forms, and of such a variety in the minutiæ composing those Forms and this difficulty also most considerably increas[d] by the various effects caused by the different situations of the Sun; that I am perswaded many considerable improvements may be made, in correctnefs of Form in the spots, their situation and distinctnefs of parts; perhaps it was too hastily concluded that the large dark parts upon the Moon's Face, were Seas; I am apprehensive, that, if the Engraver has been faithfull to his trust, this must have led that great Astronomer Cafsini to represent these parts of one almost uniformly smooth, and uvaried effect, which upon a strict inspection will appear to be full of parts as various and nearly as multitudinous, as that portion of the Moon, which has generally been considerd to be Land, and is certainly elevated above the level of the former: even in the parts of the Moon which have been most considerd by Cafsini I think it will appear some considerable room is left for improvement. But there is a defiency which I have found in all these Maps of the Moon, and that is as I before hinted in point of Effect; the just proportion is not maintain'd in the Gradations between the inherent Light and Dark parts of the Moon, by which all pleasurable distinctnefs of character is produced. It is by my attention to this circumstance, my attempts has given some satisfaction to those Gentlemen who have honord me by inspecting the preparatory Drawings.

It was my intention first to produce a representation of the Full-Moon as it is generally illuminated by the Sun, but several very respectable Astronomers favord me with their opinion, and by their approbation of one of my Crayon Drawings, which describes the Moon two days after the first quarter, very easily prevaild upon me to alter my resolution and prefer this in which the boldnefs and the exprefsive elevations of Plato, Copernicus, Tycho, and some others near the Boundary of the Line of illumination, convey so distinct an Idea of these parts opposed to those situated near the centre of the Moon which very faintly exprefs their character, compared to the former, as they are nearly lost in the general Blaze of Light. When this is compleated I mean to return to my first intention respecting the full Moon in which are to be seen a thousand pleasing particulars which I think have not been publish'd. And if my Life is prolonged I doubt not but my inclination will be to persue such other representations as may be thought most advisable.

Dr. Herschell honord me by suggesting the very same Idea with which I understand your last Favor advises, the representing the whole Face of the Moon in the manner of the internal edge of Light as described in the gibbous Moon which I have mention'd to have drawn with Crayons, composing one general

afsemblage from each days effect upon the boundary of Light where the Light and Shade are most exprefsive from the commencement to the full Moon or from thence to the end of the last quarter. I shall certainly attend to this advice with all that Respect which is due to such advisers: but I fear the advantage will not be so great as might be expected as I am apprehensive all that distintion of Dark and Light in the composition of the Moon, w[d] be lost, and also, that the Effect of elevations so pleasing and satisfactory in the edge of illumination in the Gibbous Moon, woud be indistinct and the whole appear very much confused; as the agreeable effect is produced upon this Spherical Body, by the opposition of the parts distinctly seen near the edge to those which are more faint in the united mafs of Light, giving that satisfaction to the Eye which is produced in a picture well regulated by this conduct, a principle well know' among Painters and respected by connifseurs. There is a difficulty in executing the Moon upon this plan which I have endeavord to surmount but in vain: you will I hope Sir have the goodnefs to honor me with such instruction as you may think will afsist me respecting it, it is this, I know not how to exprefs upon this plan the parts of the New Moon till four days old or the four concluding days of the last quarter consistant with the rest, I hope my meaning will be understood when you consider the parts about Mare Crisium in the early stage of the Moon, they want that exprefsion which the rest have in the progrefsion of the Suns Rays, and which they have also a short time after the full Moon. The same is applicable to the parts about Grimaldus in the last quarter, I cannot conceive how these parts are to be renderd equally exprefsive with the rest unlefs one has the light represented as coming from the Right to the Left while the other are enlightend from the Left to the Right which must be extreamly improper. I apprehend those who have deliniated the Moon at least those whose works have come under my inspection, may have proceeded upon a plan different from that which I have adopted, and what at first sight appears the most Eligible, that of determining the parts with their situations with correctnefs at the first, and then of adding the different degrees of strength to the Outline by which means they have left this material persuit the Effect of the whole together particularly imperfect, and from the embarrasing multitude of Lines some considerable mistakes have been made, in that part of the work which to them must have been considerd as the most important, viz. the size of the Spots their distance from each other and their exact situation which can be demonstrated, but wou'd add so considerably to my prolixity for me to attempt, as to add to my confusion in trespafsing more upon your Time, by that which is already so very prolix and I fear not free from an impertinent appearance.

My first efforts Sir were made with Crayons, representing the colour of the Moon in its general form according to the particular Phase, upon this I laid the larger Spots of Mediteraneum

Serenitatis Tranquilitatis &c &c—these I adjusted by degrees giving them their general Forms and grand bearings endeavouring to preserve with as much truth as time would admit the proportional difference of dark & Light; by which one part is subordinate to the other; and proceeding so long as the Moon was to be seen: executing the minutiæ as far as time would permit, being always attentive to the most considerable parts before those which are subordinate. The Effect of the Moon thus produced, surrounded by a dark Blue colour has a novelty as well as an exprefsion in its appearance, which has given some pleasure to many Gentlemen whose approbation is very flattering to me. But I am very sensible that in a Drawing of fourteen inches Diameter the crayons such as I use are not proper to exprefs the minutiæ with accuracy however proper for the effect they may be, I have therefore contented myself by making that part which was in my power something correct. I used other means in drawing the parts which are more minute, the fine point of a black Lead pencil I think the best for the purpose and have furnish'd myself with a great number of Drawings in this manner, of the different Spots in the Moon under the circumstances they present themselves in the different Phases, from these Drawings and in continual reference to the Moon itself, I am proceeding upon the larger picture, producing the effect from the Drawings made with Crayons and the small parts from those with black lead pencils.

As a painter it is no vanity for me to say, much may be done in regard to accuracy by the Eye only afsisted by the Telescope. We are used to consider the size, form and proportion of parts, it is the first principle of our Art, it must be acquired; but I have not presumed upon this imaginary power of correctnefs, the Eye is capable of being deceiv'd, and as I want to approach as near as may be to perfection, I am induced to measure the distances of as many parts as will set the rest in their proper places. As I have no micrometer such as would describe minutes &c. and if I had, thro' my inexperience and want of sufficient power of calculation, I should be embarrafs'd thro' the Moon's Variation in its Diameter, at different times. I have constructed one which serves my purpose. A hair is strain'd in the Focus of the short Tube of my Telescope, upon this Hair is made marks of different sizes and at various distances. A scale upon paper has been fixt upon a wall at a certain distance, and by this scale I have afsertain'd the size of the Marks and the Space which separates each from the other: a counter scale proportion'd to work the large picture with, is all I need to keep my mind satisfied that I do not proceed in Vain for I have by a particular method prevented the inconvenience which the want of a crofs Bar and perpendicular would otherways have occasion'd.

It will be some time before I have compleated my intention, as I have many engagements and this I only esteem as my

amusement. I do not promise to present my efforts to the public, that must depend upon circumstances.

That with which you conclude your Letter has not escaped my notice. The Libration of the Moon from North to South as well as from East to West. I am much obliged to you Sir for this and the other observations, in which you have freed me from my embarrafsments. I hope to be pardon'd if when other difficulties arise I am constrain'd to make application for your instruction.

I have the honor to be with very great Respect

Sir

Your very much obliged

and most obedient

humble servant

John Rufsell.

Mortimer Street

Febʸ 19. 1789.

Details of the Total Solar Eclipse of 1896 *August* 8–9 *for Kushiro, in the island of Yezo.*

(*Communicated by the Superintendent of the "Nautical Almanac."*)

The following details are communicated to the Society, as it is understood that Kushiro has been selected as one of the stations to be occupied by the observers of the Joint Permanent Eclipse Committee, who are going out to Japan next August. Should a second station be selected within fifty or sixty miles of Kushiro, the circumstances of the eclipse for it can be computed, with sensible accuracy, from the subjoined equations.

The details for Horonai, on the N.E. coast of Yezo, will be found in *Nautical Almanac Circular*, No. 15.

The elements adopted in the computations are those published in the *Nautical Almanac* for 1896, p. 416.

Assumed position of Kushiro... ... Long. 144° 22′ E., Lat. 42° 58′ N. (reduction to $l - 11''\cdot7$)

	d	h	m	s	Contact from N. Point.	Contact from Vertex.	Sun's Altitude.
Eclipse begins Aug.	9	2	6	46	55° W.	94° W.	53°
Totality begins „	9	3	16	52	Duration 2ᵐ 35ˢ·5		42°
Totality ends „	9	3	19	27			
Eclipse ends „	9	4	23	44	123° E.	73° E.	30°

Local mean times and *direct* image.

For any place not far distant the geocentric north latitude being l, and east longitude λ, the Greenwich mean time t of

partial beginning may be approximately computed from the following formulæ :—

$$\cos \omega = +1{\cdot}12272 - [0{\cdot}16735] \sin l + [0{\cdot}05786] \cos l \cos (\lambda - 46^\circ\ 10'{\cdot}9)$$

$$t = \text{Aug. } 8^d\ 17^h\ 38^m\ 15^s - [3{\cdot}65074] \sin \omega - [3{\cdot}65552] \sin l - [3{\cdot}84426] \cos l \cos (\lambda - 12^\circ\ 40'{\cdot}8)$$

Contact on ☉'s limb, $\omega - 34^\circ\ 31'{\cdot}1$ from the N. point towards the W.

and the Greenwich mean time of partial ending by—

$$\cos \omega = +1{\cdot}52241 - [0{\cdot}18107] \sin l + [0{\cdot}03061] \cos l \cos (\lambda - 14^\circ\ 21'{\cdot}7)$$

$$t = \text{Aug. } 8^d\ 17^h\ 12^m\ 18^s + [3{\cdot}57870] \sin \omega - [3{\cdot}55219] \sin l - [3{\cdot}78268] \cos l \cos (\lambda + 19^\circ\ 13'{\cdot}1)$$

Contact on ☉'s limb, $\omega + 31^\circ\ 48'{\cdot}0$ from the N. point towards the E.

Also the Greenwich mean times of the beginning and ending of totality may be approximately computed from the following formulæ in which the upper sign applies to the beginning, and the lower sign to the ending :—

$$\cos \omega = +70{\cdot}69521 - [1{\cdot}88965] \sin l + [1{\cdot}76504] \cos l \cos (\lambda - 29^\circ\ 43'{\cdot}0)$$

$$t = \text{Aug. } 8^d\ 17^h\ 19^m\ 17^s \mp [1{\cdot}89913] \sin \omega - [3{\cdot}61011] \sin l - [3{\cdot}81343] \cos l \cos (\lambda + 3^\circ\ 38'{\cdot}3)$$

The quantities in square brackets are logarithms, those in the second equation of each pair being logarithms of seconds of time.

"*Nautical Almanac*" *Office :*
1896 *January* 2.

On the Proper Motion of μ Cassiopeiæ. By W. T. Lynn, B.A.

In the upper part of the left arm of *Cassiopeia*, Bayer has marked two stars, but appears to have inadvertently omitted to letter the brighter one on his map of the constellation. But from the subsequent letterpress it is clear that he intended to indicate it by the letter θ. The fainter star in its immediate proximity he marked by the Greek letter μ. This latter star has long been well known to be endowed with a large proper motion in both elements, whilst the proper motion of θ is very small. In some future age it may perhaps be found that μ is in orbital motion round θ, and a very gigantic motion this would be. No attempt has yet been made to determine the parallax of the latter ; but the late Professor Pritchard obtained an approximate measurement of that of μ by the photographic method, the result being (value found, $0''{\cdot}04$), that its large proper motion is not due to any special proximity.

Bessel long ago showed that this proper motion was essentially confirmed by the observations of the star made by Tycho Brahé. My present object is to deduce its accurate value, from those which have been obtained, chiefly at Greenwich, during the last fifty years. Below are tabulated the results from the Twelve-Year, Seven-Year for 1860, Nine-Year and Ten-Year Greenwich Catalogues (no observations of the star were made in the periods covered by the Six-Year and the second Seven-Year Catalogues), and the latest Radcliffe Catalogue, which is reduced to the epoch of 1890.

Catalogue.	Epoch.	R.A. h m s	N.P.D. ° ′ ″
12-year	1840	0 57 40·42	35 52 2·68
,,	1845	...	35 50 34·38
7-year	1860	0 58 58·93	35 46 5·77
9-year	1872	0 59 46·205	35 42 30·10
10-year	1880	1 0 17·736	35 40 8·15
Radcliffe	1890	1 0 57·167	35 37 10·15

The differences between these (omitting the observations, in one element only, of the second part of the Twelve-Year), are

	In R.A. m s	In N.P.D. ′ ″
20 years	+1 18·51	−5 56·91
12 years	+0 47·275	−3 35·67
8 years	+0 31·531	−2 21·95
10 years	+0 39·431	−2 58·00

From these result the annual changes—

	In R.A. s	In N.P.D. ″
1840–1860	+3·926	−17·846
1860–1872	+3·940	−17·972
1872–1880	+3·941	−17·744
1880–1890	+3·943	−17·800

Now the precession during the successive periods may be taken as $+3^s{\cdot}537$, $+3^s{\cdot}548$, $+3^s{\cdot}554$, and $+3^s{\cdot}560$ in R.A., and $-19''{\cdot}410$, $-19''{\cdot}388$, $-19''{\cdot}370$, and $-19''{\cdot}356$ in N.P.D. Subtracting these, we obtain for the proper motion—

	In R.A. s	In N.P.D. ″
1840–1860	+0·389	+1·564
1860–1872	+0·392	+1·416
1872–1880	+0·387	+1·626
1880–1890	+0·383	+1·556

All these results are derived from a considerable number of observations, and the mean result, $+0^s\cdot3878$ in R.A. and $+1''\cdot540$ in N.P.D., is probably a very accurate value of the proper motion of this star. It differs slightly from that adopted in both the Greenwich Ten-Year Catalogue and the Radcliffe Catalogue for 1890, which is $+0^s\cdot3860$ in R.A. and $+1''\cdot580$ in N.P.D.

We will now compare the latest place, that given in the Radcliffe Catalogue, with that deduced from Bradley's observations, as given in Professor Auwers's *Neue Reduction*. The place in the latter, which is for the epoch 1755, is R.A. $0^h\ 52^m\ 9^s\cdot59$, and declination $+53°\ 42'\ 35''\cdot5$ = N.P.D. $36°\ 17'\ 24''\cdot5$. From this, by the aid of the successive precessions given by Auwers and that in the Radcliffe Catalogue (all founded on Struve's constant), we obtain for Bradley's place, reduced to 1890,

R.A. $1^h\ 0^m\ 5^s\cdot01$, N.P.D. $35°\ 33'\ 38''\cdot70$.

The actual place for this date, as given in the Radcliffe Catalogue, is

R.A. $1^h\ 0^m\ 57^s\cdot167$, N.P.D. $35°\ 37'\ 10''\cdot15$,

differing from the former by $+52^s\cdot157$ and $+3'\ 31''\cdot45$. The difference between the two epochs being 135 years, this gives for the annual proper motion $+0^s\cdot386$ in R.A., and $+1''\cdot566$ in N.P.D.; a result in very satisfactory agreement with that which I have deduced above from the later Greenwich and Radcliffe Catalogues.

Blackheath: 1895 *December* 9.

Description of a Spectroscope (the Bruce Spectroscope) recently constructed for use in connection with the 25-inch Refractor of the Cambridge Observatory. By H. F. Newall, M.A.

The spectroscope which is described in the present note has lately been constructed for use in connection with the 25-inch visual refractor (the Newall telescope) of the Cambridge Observatory.

It has been arranged solely for photographing spectra, and no provision has been made for visual micrometric measurements.

In designing the spectroscope, and especially in deciding on what may be described in general terms as a single-prism spectroscope, I have been guided by the following considerations. The brighter stars in the northern hemisphere have been studied in considerable detail, and provision has been made for their being further studied at many observatories. A new instrument to be used in connection with an equatorial of large light-collecting

power should be designed chiefly with a view to rendering work of high precision possible in the case of the fainter stars. For work of high precision it seems best at present to adopt a spectroscope with collimator and slit, and to provide arrangements for getting comparison spectra from terrestrial sources.

In the case of faint stars, the primary difficulty is to get a photograph at all, however little the purity or definition of the spectrum. It is therefore of the greatest importance to adopt arrangements which involve as little loss of light as possible in the spectroscope itself, and which ensure that as much as possible of the light collected by the object-glass of the equatorial shall pass into the slit of the spectroscope.

Preliminary work with spectroscopes of various constructions has shown that it would be necessary to modify the colour correction of the visual refractor by some auxiliary lens, or else to put up with a very limited range of spectrum. The difficulties which arise in consequence of imperfect achromatism, in spectroscopic investigations made in connection with large refractors, have been described by many observers; most recently by Keeler with reference to the Lick telescope (*Astroph. Jour.* 1895, I. p. 102), and by Belopolsky with reference to the Pulkova refractor (*Astroph. Jour.* 1895, I. p. 366).

The spectroscope may be briefly described as having a single large white-flint prism, transmitting a beam of light of circular section and 2 inches in diameter, and having a camera of fixed length, in which may be used either (1) an ordinary object-glass for giving a short spectrum of a very faint star, the spectrum being in this case 19·9 mm. long from H_β to midway between H and K, or (2) a telephoto-combination arranged so as to effectively double the length of the camera for giving a greater linear dispersion for medium stars, the spectrum being in this case 44·5 mm. long for the same range as above stated.

It is perhaps of interest to record here the linear extent of the spectrum from H_β to midway between H and K (the same range as above) for some of the spectrographs lately used by Dr. Vogel at Potsdam (*Astroph. Jour.* 1895, p. 200).

No. I., used for velocity in line of sight,	69· mm.
No. II., used for spectra of *Mars* or *Jupiter*,	16· mm.
No. III., used for *Nova Aurigæ*,	7·0 mm.
No. IV., used for *β Lyræ*,	8·6 mm.

The mode of attachment to the refractor is, I believe, unusual, and may be briefly described as follows:—

A correcting lens is inserted in the cone of rays coming from the object-glass of the refractor. It is set about 5 feet from the uncorrected focus; and the corrected focus is nearer to the object-glass by about 18 inches. (The effective focal length of the combination is about 20½ feet.) The corrected focus is thus drawn up inside the refractor.

The spectroscope is pushed up partly into the tube of the refractor so that the slit coincides with the corrected focus.

In this arrangement many advantages are gained, notably the following :—

(1) An improved colour correction results.
(2) Strength is gained in the attachment of the spectroscope to the eye-end.
(3) Space is economised, for the spectroscope is 18 inches nearer to the object-glass of the refractor.
(4) The whole spectroscope, being attached to a strong framework which is clamped to the focussing tube of the refractor, can be moved bodily in and out (for the purpose of focussing the star on the slit) without altering the adjustment of the parts of the spectroscope.
(5) The convergency of the cone of rays from the object-glass of the refractor can be arranged to have a very convenient value ; the convergency for the uncorrected object-glass is about 1 in 14·0, and with the correcting lens it becomes 1 in 10.
(6) As a consequence of the altered convergency, the requisite resolving power can be attained in the single prism with shorter collimator.

The one drawback that I realise at present is that, since the relation between the purity P, the resolving power R, and slit width s, and the ratio ψ of aperture to focal length, is

$$P = \frac{\lambda}{s\psi + \lambda} R,$$

it is clear that the slit-width must, for a given purity and resolving power, vary inversely as ψ. This I regard as a great disadvantage ; but it has seemed to me that there was a balance of advantage in favour of the lens.

I was at first inclined to think that the inaccessibility of the slit was an insuperable objection. But the adoption of Huggins' admirable plan of a reflecting slit-plate has got over all the anticipated difficulties.

Having thus briefly indicated the general method adopted, I proceed to describe some of the details.

The Eye-end or Breech-piece of the 25-inch Refractor.

No doubt many of the conveniences of the adopted method of attaching the spectroscope depend on the arrangement of the eye-end of this special refractor. The sturdy massiveness of Cooke's work has formed a splendid foundation, to which the spectroscope has been fitted.

The steel tube of the refractor is cigar-shaped, wider in the middle than at the ends. At the eye-end the steel tube has a diameter of 21 inches, and to it is fitted a strong iron casting

THE EYE-END OF THE NEWALL TELESCOPE WITH THE *SPECTROSCOPE* ATTACHED.

which contracts the opening with a rapid taper down to 8½ inches, and forms a strengthening piece with a turned flange. Into the opening thus left is fitted a massive breech-piece (an arrangement of draw tubes, position circle and focussing mechanism), ending in a flange with a kind of bayonet joint, to which the various adapters for eye-pieces, micrometer solar eye-pieces, &c., can be fitted. All apparatus fitted to the bayonet joint can be rotated in connection with the position circle, and can be racked in and out by means of the focussing screw through a range of 4 inches. The breech-piece weighs about 1½ cwt., and its weight gives an idea of its strength. It is to this bayonet-joint flange, the aperture of which is 5¾ inches in diameter, that the spectroscopic appliances are attached. The plane of the flange, when racked in as far as the focussing screw will take it, is about 7¾ inches nearer to the object-glass than the uncorrected focal plane.

The Correcting Lens.

A simple convexo-concave lens of aperture 5 inches, and of focal length 154 inches for light of wave-length 5890–6 λ is set in the convergent beam of rays coming from the object-glass of the refractor at a distance of about 62 inches from the focus, or, as I shall now call it, the uncorrected focus. The corrected focus is about 18 inches nearer to the object-glass.

The lens is mounted at the end of a brass tube, and the other end of the tube is provided with a heavy flange. The tube is pushed, lens first, into the refractor, and the flange is clamped into the bayonet joint at the end of the breech-piece.

The position of the lens can be altered by the focussing screw, but when the lens is pushed in as far as it will go, then the new, or corrected, focus is inside the tube which holds the correcting lens about 11 inches from the new flange on the breech-piece.

It is unnecessary to go into details concerning such a lens, inasmuch as Keeler has recently published (*Astroph. Jour.* 1895, i. p. 101) a note on work which is in great measure identical with that which I undertook in considering the possibility of getting a satisfactory improvement of the colour curve with a simple lens. Keeler has rejected the solution "for the general case of large telescopes," on the ground that the alteration which the use of such a lens would produce in the aperture of the convergent beam (*i.e.* the ratio of the diameter of the cross section of the convergent beam to the distance of the cross section considered from the focal plane) is excessive. In the case he considers the ratio is altered from 1 : 19 to 1 : 5, and this would involve the use of a collimator of such unusual proportions as to be impracticable.

But the question is—is it possible to produce a considerable change in the colour correction without excessive change in the ratio referred to? Elementary calculations, similar to those published by Keeler, showed that it was worth while to have a lens

made, and experimental determinations of the corrected separation of the foci for different colours for the actual correcting lens used have convinced me that the improvement is considerable. It is clear that if the separation of the foci were reduced only in the same proportion as the convergency ratio, no advantage would be gained; when one of two colours was in focus on the slit the circle of aberration for the other colour would be just as great as without the correcting lens.

My lens is arranged to give a convergent beam, with ratio 1 : 10, whilst the uncorrected object-glass has a ratio 1 : 14·0. Under these circumstances the collimator of the spectroscope is of very convenient dimensions—namely, 2 inches aperture and 20 inches focal length. A comparison of the diameter of the circles of aberration on the slit, first for the uncorrected object-glass and second for the corrected object-glass, shows clearly the advantage gained. If the light focussed on the slit in each case is light of wave-length 4860 λ (H_β), the circles of aberration deduced from actual measurement for H_γ and H_δ have diameters as follows:—

	Uncorrected O.G. mm.	With Correcting Lens. mm.
H_β	0·00	0·00
H_γ	0·81	0·36
H_δ	1·94	0·97

Photographs of star spectra are satisfactorily uniform from λ 5896 (D) to λ 4470. I refer here to uniformity of density; in another place I give suggestions as to a cause of unsatisfactory definition at the ends.

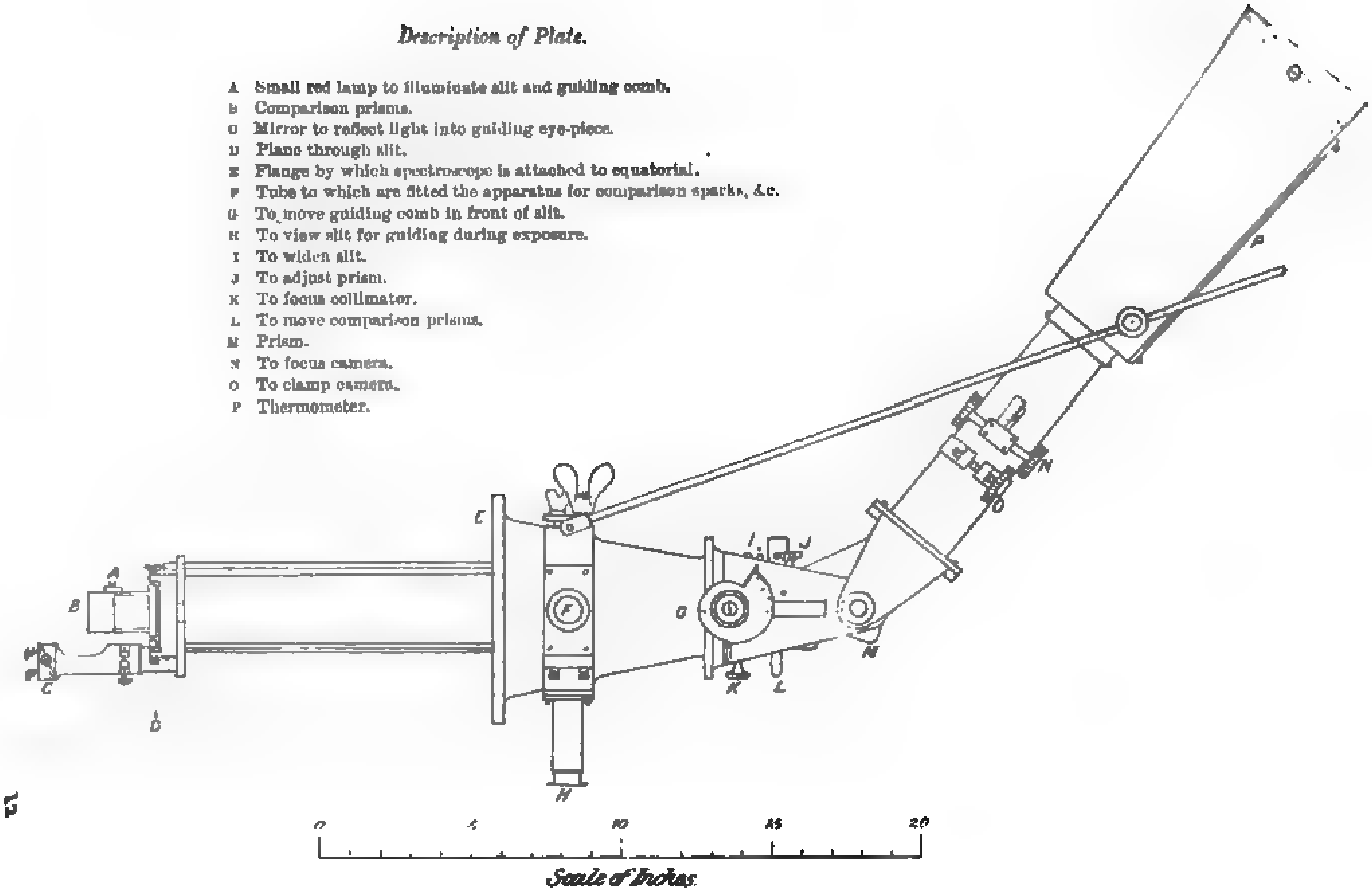
The following point with respect to the focussing of the star on the slit may be noted. The distance between the slit and the correcting lens is fixed when the collimator is clamped in the framework. The focussing is accomplished by moving both spectroscope and correcting lens simultaneously in or out by means of the focussing screw. The distances between the correcting lens and the conjugate foci are so related that the movement of the lens and spectroscope through any given small distance produces a movement of the star-image through nearly exactly one-half that distance with respect to the slit. The focussing, which is of great importance, can thus be done with great accuracy.

The Framework of the Spectroscope.

The frame of the spectroscope consists of a heavy hollow conical casting of gun-metal with a flange at each end. The larger flange is that by which the whole spectroscope is clamped to the equatorial by means of four large thumb-screws; to the smaller flange is attached a strong ribbed aluminium casting, carrying the pivots about which the whole camera can turn, and *between* which the prism is mounted.

Description of Plate.

A Small red lamp to illuminate slit and guiding comb.
B Comparison prisms.
C Mirror to reflect light into guiding eye-piece.
D Plane through slit.
E Flange by which spectroscope is attached to equatorial.
F Tube to which are fitted the apparatus for comparison sparks, &c.
G To move guiding comb in front of slit.
H To view slit for guiding during exposure.
I To widen slit.
J To adjust prism.
K To focus collimator.
L To move comparison prisms.
M Prism.
N To focus camera.
O To clamp camera.
P Thermometer.



The collimator is held in the conical casting, the lens projecting through a hole in the smaller flange and the aluminium casting, and the plane of the slit being about 11 inches from the plane of the larger flange. The whole collimator is arranged to slide through a small range (about ½ inch) so that the distance between the slit and the flange may be adjusted. The final focussing of the star-image on the slit is accomplished by moving the whole spectroscope in or out by means of the large focussing screw on the breech-piece.

About midway between the flanges on the conical casting the casting is thickened, so that a cylindrical ring is formed which facilitates the attachment of several accessory arrangements: (i) a telescope and reflectors to enable the observer to view the slit as from in front; (ii) condensing lenses and reflectors to throw an image of a spark or tube for comparison spectra upon the slit; (iii) a clamping-screw to hold the stay-rods by which the camera is prevented from turning about the pivots; and several other small things which it is not necessary to specify.

The Collimator and Slit and Guiding Comb.

The collimator has a focal length of 20½ inches (520 mm.) and an aperture of 2⅛ inches (54 mm.), the object-glass being a visual achromatic.

The stout collimator tube is made so that it can slide through a small range in the frame of the spectroscope; and when the tube is clamped in position the object-glass can be moved relatively to the slit by means of a rack and pinion. A scale is attached by which the focus-reading can be read off.

The slit is arranged after the admirable device of Dr. Huggins. The jaws are made of speculum-metal, and the exposed faces are highly polished, so as to form a single plane surface, which is inclined at a small angle to the axis of collimation. Great care was taken to work the sharp edges in a proper manner.

When the image of a star is thrown upon the slit, some portion of the light passes through the slit; the rest is reflected by the polished faces of the jaws on to a small mirror, fixed in front of the slit and displaced slightly to one side, so as not to interfere with the incident pencil. The mirror, together with a system of lenses and a reflecting prism, enables the observer to view the slit: he looks into an eyepiece attached to the conical framework in a direction perpendicular to the axis of the collimator, and sees the slit and any images (whether of star or of spark for comparison spectra) that may fall upon it from the proper quarter.

In front of the slit is set a small movable guiding comb, which enables the observer to set the star-image on any required part of the slit. The teeth of the comb cover certain parts of the slit, and leave the rest exposed. By a suitable mechanism the comb can be either moved by a very small amount up and down the slit, or altogether withdrawn so as to expose the whole

slit. By making the teeth of the comb twice as wide as the gap between them, it is arranged that three spectra can be set side by side—*e.g.* a star spectrum taken between two spark spectra, one of which is taken before, the other after, the star spectrum. In this mode of procedure any changes of adjustment that may have arisen during the exposure for the star spectrum, in consequence of change of temperature or in the positionof the spectroscope, may be at once detected in the photograph.

The beautiful device of Dr. Huggins's reflecting slit is only open to one objection, so far as I am aware. Let us suppose it is desired to investigate a spectrum near Hγ. In this case it is necessary to focus Hγ-light on the slit and to keep it on the slit. It is difficult to do this, in consequence of the chromatic aberration of the equatorial; but the following device has proved efficacious. From time to time the star is observed on the slit with a small direct-vision compound prism held between the eye and the guiding eyepiece in such a way that the length of the spectrum is parallel to the length of the slit. The slit then appears as a fine dark line running along the length of the spectrum, which is narrow at the part or parts focussed on the slit, and has at any other part a width determined by the diameter of the circle of aberration of the light corresponding to that part. The star is then moved until the narrow parts of the spectrum fall on the slit. The prism is then removed, and the position of the slit with respect to the slightly blurred star-image is noted, so that guiding can be continued with only occasional recourse to the prism.

In such work as the investigation of the spectrum of special parts of a planet or a nebula the reflecting slit is invaluable.

The Prism.

The prism at present used is a white dense flint prism of 60°. The height is $2\frac{1}{8}$ inches (54 mm.), and the length of the side of the triangular section is $3\frac{3}{8}$ inches (86 mm.).

The resolving power for	λ 5896	is about	7600;	$\delta\lambda$ =	·8	tenth-metre.
„	„	λ 5000	„	12000	„	·4	„
„	„	λ 4250	„	22000	„	·2	„

The edges and angles of the prism are all ground blunt, and the prism is partly encased in aluminium sheet, which is bent so as to cover the triangular faces (the "top" and the "bottom") of the prism and also the ground rectangular base, but so as to leave the two polished rectangular faces free. Two small gun-metal bosses are fitted to the aluminium case, one fixed on the bottom, the other being adjustable within small limits on the top of the prism. Fine centre-holes are drilled through the bosses and the line joining them is made parallel to the refracting edge, the final adjustment being made by moving the adjustable boss by four crews. Two screws with fine conical points pass through the pivots about which the camera turns, and the prism is held in its

case between these conical points or male centres, which are screwed through the pivots into the female centres in the bosses. The prism thus held is free to turn about an axis through the male centres. An arm projecting from the top of the prism-case is pressed by a spring against the end of a screw which is fixed to the frame-work, and a slow motion for adjusting the prism for minimum deviation is thus provided.

This mode of holding the prism has proved very satisfactory. The slit at the end of the collimator is adjusted to parallelism with the line joining the male centres, and this ensures parallelism with the refracting edge of the prism, provided that the line through the female centres has been adjusted.

The Camera.

The camera is made of a brass tube about 10 inches long joined rigidly to a tapered box of rectangular section, made of aluminium sheet and having a length of 10 inches. The total length of the camera is thus 20 inches.

The following object-glasses can be used in it, each having an aperture of $2\frac{1}{8}$ inches (54 mm.).

(1) A visual achromatic object-glass of focal length 20 inches (508 mm.).

(2) A plano-convex quartz lens of focal length 20 inches. The use of an uncorrected lens of this kind is convenient when flat photographic plates are used. With two similar achromatic lenses in the collimator and camera, the result of the over-correction of both lenses is to give a spectrum which cannot be in focus over a considerable range unless a curved plate or film is used. If an uncorrected lens is used in the camera in connection with an over-corrected lens in the collimator, the spectrum is flatter. Whether it is better to use glass or quartz for the simple lens depends upon the character of the colour correction of the achromatic object-glass used in the collimator.

In laboratory work I have used a spectacle lens of 36 inches focal length in connection with an over-corrected "achromatic" collimating lens and have got admirable spectra from the D lines to the λ 3800 photographed in sharp focus on a single flat plate without tilting the plate. I have not seen the method described, but it is so simple that it is most probably known.

(3) A telephoto-combination, designed and used in such a way as to have an equivalent focal length of about 40 inches (1016 mm.) though the extreme *actual* length of the camera is the same as with the other object-glasses, namely 20 inches (508 mm.).

The use of this optical device was only decided upon after numerous experiments, and I take this opportunity of expressing my obligations to Messrs. Dallmeyer for their kindness in letting me try some of their combinations before having a pair made for use in this spectroscope.

If justification of the use of this method be required, it may be based on the following considerations. The prism used is of such dimensions that the resolving power is considerably higher than that which a photographic film with its markedly granular structure can ever do justice to. The theoretical resolving power of my prism is a little more than one of Professor Vogel's compound prisms. Professor Vogel * has expressed the opinion that the performance of his prisms would have warranted a large increase in the focal length of the camera, but such an increase would have increased the linear dispersion so much that only the brightest stars could have been observed with the Potsdam Refractor. The question therefore presents itself: Is it better to use two prisms and a short camera or one prism and a long camera? The only considerations which bear on the point are practical, and it appears to me that the coarseness of granularity of available photographic plates is the most important factor; for it would seem useless to employ an optical resolving power greater (except by an arbitrary amount for margin) than the defining power of the photographic plate. If the necessary resolving power can be attained with a single prism of manageable dimensions, the balance is in favour of the single prism, for it involves a smaller loss of light.

Scales on the Instrument.

The importance and convenience of having scales on the instrument, by which every adjustment of every adjustable part can be recorded, cannot be over-estimated.

The following scale readings are taken for each exposure made on the telescope.

1. Position angle of the slit, usually 90°.

2. Focus reading, localising the position of the slit amongst the coloured images of the star formed on the collimation axis of the equatorial.

3 and 4. Focus readings of the collimator and camera.

5. Inclination of the photographic plate.

6. The inclination of the axes of camera and collimator.

7. Width of the slit.

8. Temperature recorded by a thermometer attached to the camera.

9. The part of the slit exposed at different times during any exposure.

There is still needed a tenth scale to record the position of the prism.

Some Numerical Details.

The weight of the spectroscope is 26 lbs.; the weight of the flanged tube which holds the correcting lens, 13 lbs.

Assuming, for the sake of definiteness, that determinations of radial velocity would be made by measurements near H_γ, the

* *Publn. d. Astroph. Obs. zu Potsdam*, 1892, vol. vii. pp. 20 and 21.

following details give a more precise idea of the conditions under which such measurements could be made with the spectroscope described in this note.

The spectrum near H_γ has a linear dispersion 1 mm. to 21 λ (tenth-metres). Taking the minimum measurable quantity to be $0^{mm}\cdot001$, this would correspond to $0^{\lambda}\cdot021$, or to 1·5 km./sec., or 0·9 mile/sec. (In Vogel's classical researches, $0^{mm}\cdot001$ corresponded to $0^{\lambda}\cdot013$, or 0·9 km./sec., or 0·6 mile/sec.)

The diameter of the first diffraction ring in the corrected image formed by the object-glass of the equatorial and the correcting lens is, for H_γ, $0^{mm}\cdot011$.

Near H_γ, since the resolving power of the prism is 22000, the purity of the spectrum can never be advantageously greater than 7000. The following table shows the relation between the purity and the slit-width.

Purity.	Slit-width. mm.	Spectrum pure enough to separate two lines for which $\delta\lambda$ is
7300	0·0086	0·60 tenth metre
5500	0·025	0·79 "
4340	0·035	1·00 "

Actual measurement shows that the distance between the centres of neighbouring grains on a photographic film of average goodness lies between $0^{mm}\cdot01$ and $0^{mm}\cdot035$, and a fair average value seems to be $0^{mm}\cdot02$ or $0^{mm}\cdot025$. With the telephoto camera the image of the slit is twice as wide as the actual slit. It is thus seen that, with a slit-width $0^{mm}\cdot025$, the image on the plate involves two grains in its width.

It will be noted that the width of slit is, in the case just dealt with, twice as wide as the diameter of the first diffraction-ring in the star image. It would seem to me to be convenient to introduce the term "tremor-disc." The name more or less explains itself: it is easiest to state what it is intended to convey by reference to a photograph of a star taken with a long exposure. The star-image moves about on the plate in consequence of atmospheric tremor, and produces its effect at each spot on which it rests; the developed image is strongest where the star has most frequently rested; the distribution of density is probably symmetrical about the mean position of the star, and the intensity at different points along a diameter of the resulting tremor-disc is probably fairly well represented by a "law of errors" curve. Apart from the photograph, which shows the summation of the effects, the tremor-disc may be conceived as existing in time, so to speak; and the effect produced in a slit-spectroscope depends on the relation between a certain area of tremor-disc and the area of the slit illumined by it. The tremor-disc is of greater importance, so far as the design of a stellar spectroscope is concerned, than the diffraction-disc, which has generally been considered.

The tremor-disc at Cambridge frequently has a diameter of

8″ or even 10″; and on average nights it is probably fully 5″. Assuming that the bright central part is 3″, this would be a disc whose linear diameter is 0·09 mm., and whose area is three times as great as the illumined part of the widest slit which it is thought advisable to use.

The instrument has been named the Bruce Spectroscope, since it is one of the numerous outcomes of Miss Bruce's Grant in Aid of Astronomical Research. A portion of this grant was through Professor E. C. Pickering awarded to Professor Adams for the purchase of an instrument for the Cambridge Observatory; and it was decided to use it in providing a spectroscope for the 25-inch refractor. As the spectroscope is, in this sense, of American origin, it is a special satisfaction to record that the optical parts were (with the exception of the Dallmeyer telephoto combination above referred to) made in America. They were supplied by Mr. Brashear, of Allegheny, and the excellence of their finish and performance is admirable. The mechanical parts of the instrument were made by the Cambridge Scientific Instrument Company; and I gladly take this opportunity of saying how much their care in carrying out the somewhat troublesome design, and the ingenuity with which many difficulties were overcome, have contributed to the success of the instrument.

At the present moment I am not quite prepared to express a final opinion on the success of the general design of the instrument, for there are some points on which I wish to have more precise knowledge. I had hoped to have gained that knowledge before presenting this description, but the weather has been so unfavourable—there has not been a single observing night in the past four weeks—that my hopes have been frustrated, and it has seemed better to present the description at once and leave for a later communication some account of the points I have referred to.

Meanwhile it will probably be of interest to give the following particulars with reference to the spectra photographed with the telephoto camera and with a slit-width of $0^{mm}{\cdot}02$.

With an exposure of 7 minutes, the spectrum of *Venus* comes up with excellent clearness.

With an exposure of 10 minutes, the spectrum of α *Lyræ* from D to H_γ is over-exposed in some parts.

An exposure of 20 minutes gives the spectrum of α *Aurigæ* at H_γ at its best.

An exposure of 30 minutes is enough for γ *Cassiopeiæ*, and with this exposure the doubleness of the bright hydrogen lines, H_β and H_γ is clearly seen.

An exposure of 40 or 50 minutes is required to give a spectrum showing the green bands in α *Orionis* satisfactorily. With this exposure the spectrum is shown from D to λ 4400.

It should, however, be stated that the width of the spectrum is, in the case of the stars, small—rather less than 1 mm. This small

width is found enough for measurement with the microscope, and I have not as yet made any wider spectra for inspection without the microscope.

Expressions for the Elliptic Coordinates of a Moving Point to the Seventh Order of Small Quantities. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The mathematical investigations of the Lunar Theory based upon the variations of the elliptic elements have been carried to the seventh order of small quantities. And this requires for completeness the use of the elliptic coordinates to the same order.

But I have failed to find the complete expressions for these coordinates to the seventh order in any of the books in the Observatory library to which I have referred.

I have, therefore, determined these expressions for my own use. And, as they have been found quite independently, they will serve as a verification of any existing results.

The notation adopted is that of Delaunay's "Théorie de la Lune."

The expressions for r, v, V, and U agree identically, to the sixth order of the small quantities, with those given by Delaunay on pages 19 and 55–59, vol. i., of the "Théorie de la Lune," and adopted by him in the formation of the general expression of the disturbing function R. But it appears that Delaunay has subsequently allowed for the terms of the seventh order in the expressions for the elliptic coordinates, with the exception of the terms multiplied by e^7 and γ^7 and the coefficients of periodical terms involving the angle $(7l)$; and he must therefore have been in possession of the complete expressions to the seventh order.

$$
\begin{aligned}
\frac{r}{a} = {} & 1 + \frac{1}{2}e^2 \\
& + \cos l \left(-e + \frac{3}{8}e^3 - \frac{5}{192}e^5 + \frac{7}{9216}e^7\right) \\
& + \cos 2l \left(-\frac{e^2}{2} + \frac{e^4}{3} - \frac{e^6}{16}\right) \\
& + \cos 3l \left(-\frac{3}{8}e^3 + \frac{45}{128}e^5 - \frac{567}{5120}e^7\right) \\
& + \cos 4l \left(-\frac{1}{3}e^4 + \frac{2}{5}e^6\right) \\
& + \cos 5l \left(-\frac{125}{384}e^5 + \frac{4375}{9216}e^7\right) \\
& + \cos 6l \left(-\frac{27}{80}e^6\right) \\
& + \cos 7l \left(-\frac{16807}{46080}e^7\right)
\end{aligned}
$$

$$
\left\{
\begin{aligned}
v = g + l. & \\
& + \sin l \left(+ 2e - \frac{e^3}{4} + \frac{5}{96}e^5 + \frac{107}{4608}e^7 \right). \\
& + \sin 2l \left(+ \frac{5}{4}e^2 - \frac{11}{24}e^4 + \frac{17}{192}e^6 \right). \\
& + \sin 3l \left(+ \frac{13}{12}e^3 - \frac{43}{64}e^5 + \frac{95}{512}e^7 \right). \\
& + \sin 4l \left(+ \frac{103}{96}e^4 - \frac{451}{480}e^6 \right). \\
& + \sin 5l \left(+ \frac{1097}{960}e^5 - \frac{5957}{4608}e^7 \right). \\
& + \sin 6l \left(+ \frac{1223}{960}e^6 \right). \\
& + \sin 7l \left(+ \frac{47273}{32256}e^7 \right).
\end{aligned}
\right.
$$

$$
\left\{
\begin{aligned}
\frac{a}{r} = 1. & \\
& + \cos l \left(+ e - \frac{e^3}{8} + \frac{e^5}{192} - \frac{e^7}{9216} \right). \\
& + \cos 2l \left(+ e^2 - \frac{e^4}{3} + \frac{e^6}{24} \right). \\
& + \cos 3l \left(+ \frac{9}{8}e^3 - \frac{81}{128}e^5 + \frac{729}{5120}e^7 \right). \\
& + \cos 4l \left(+ \frac{4}{3}e^4 - \frac{16}{15}e^6 \right). \\
& + \cos 5l \left(+ \frac{625}{384}e^5 - \frac{15625}{9216}e^7 \right). \\
& + \cos 6l \left(+ \frac{81}{40}e^6 \right). \\
& + \cos 7l \left(+ \frac{117649}{46080}e^7 \right).
\end{aligned}
\right.
$$

$$
\begin{aligned}
V = h + g + l. & \\
& + \sin l \left(+ 2e - \frac{e^3}{4} + \frac{5}{96}e^5 + \frac{107}{4608}e^7 \right). \\
& + \sin 2l \left(+ \frac{5}{4}e^2 - \frac{11}{24}e^4 + \frac{17}{192}e^6 \right). \\
& + \sin 3l \left(+ \frac{13}{12}e^3 - \frac{43}{64}e^5 + \frac{95}{512}e^7 \right). \\
& + \sin 4l \left(+ \frac{103}{96}e^4 - \frac{451}{480}e^6 \right). \\
& + \sin 5l \left(+ \frac{1097}{960}e^5 - \frac{5957}{4608}e^7 \right).
\end{aligned}
$$

$$+\sin 6l\left(+\frac{1223}{960}e^6\right).$$

$$+\sin 7l\left(+\frac{47273}{32256}e^7\right).$$

$$+\sin(2g+2l)\left[-\gamma^2-\gamma^4+4\gamma^2e^2-\gamma^6+4\gamma^4e^2-\frac{55}{16}\gamma^2e^4\right].$$

$$+\sin(2g+3l)\left[-2\gamma^2e-2\gamma^4e+\frac{27}{4}\gamma^2e^3-\frac{207}{32}\gamma^2e^5+\frac{27}{4}\gamma^4e^3-2\gamma^6e\right].$$

$$+\sin(2g+l)\left[+2\gamma^2e+2\gamma^4e-\frac{7}{4}\gamma^2e^3+\frac{5}{96}\gamma^2e^5-\frac{7}{4}\gamma^4e^3+2\gamma^6e\right].$$

$$+\sin(2g+4l)\left[-\frac{13}{4}\gamma^2e^2-\frac{13}{4}\gamma^4e^2+\frac{259}{24}\gamma^2e^4\right].$$

$$+\sin(2g)\left[-\frac{3}{4}\gamma^2e^2-\frac{3}{4}\gamma^4e^2-\frac{1}{8}\gamma^2e^4\right].$$

$$+\sin(2g+5l)\left[-\frac{59}{12}\gamma^2e^3+\frac{3221}{192}\gamma^2e^5-\frac{59}{12}\gamma^4e^3\right].$$

$$+\sin(2g-l)\left[\frac{1}{12}\gamma^2e^3-\frac{5}{192}\gamma^2e^5-\frac{1}{12}\gamma^4e^3\right].$$

$$+\sin(2g+6l)\left[-\frac{115}{16}\gamma^2e^4\right].$$

$$+\sin(2g-2l)\left[-\frac{1}{24}\gamma^2e^4\right].$$

$$+\sin(2g+7l)\left[-\frac{9893}{960}\gamma^2e^5\right].$$

$$+\sin(2g-3l)\left[-\frac{9}{320}\gamma^2e^5\right].$$

$$+\sin(4g+4l)\left[+\frac{1}{2}\gamma^4+\gamma^6-8\gamma^4e^2\right].$$

$$+\sin(4g+5l)\left[+2\gamma^4e-\frac{85}{4}\gamma^4e^3+4\gamma^6e\right].$$

$$+\sin(4g+3l)\left[-2\gamma^4e+\frac{45}{4}\gamma^4e^3-4\gamma^6e\right].$$

$$+\sin(4g+6l)\left[+\frac{21}{4}\gamma^4e^2\right].$$

$$+\sin(4g+2l)\left[+\frac{11}{4}\gamma^4e^2\right].$$

$$+\sin(4g+7l)\left[+\frac{137}{12}\gamma^4e^3\right].$$

$$+\sin(4g+l)\left[-\frac{17}{12}\gamma^4e^3\right].$$

$$+\sin(6g+6l)\left[-\frac{1}{3}\gamma^6\right].$$

$$+\sin(6g+7l)\left[-2\gamma^6e\right].$$

$$+\sin(6g+5l)\left[+2\gamma^6e\right].$$

$$U = \sin(g+l)\left[2\gamma - 2\gamma e^2 - \frac{1}{4}\gamma^3 + \frac{7}{32}\gamma e^4 - \frac{5}{144}\gamma e^6 + \frac{1}{4}\gamma^3 e^2 + \frac{3}{8}\gamma^7\right].$$

$$\sin(g+2l)\left[2\gamma e - \frac{5}{2}\gamma e^3 - \frac{1}{4}\gamma^3 e + \frac{17}{24}\gamma e^5\right].$$

$$\sin g\left[-2\gamma e + \frac{1}{4}\gamma^3 e\right].$$

$$\sin(g+3l)\left[+\frac{9}{4}\gamma e^2 - \frac{27}{8}\gamma e^4 + \frac{765}{512}\gamma e^6 - \frac{9}{32}\gamma^3 e^2\right].$$

$$\sin(g-l)\left[-\frac{1}{4}\gamma e^2 + \frac{1}{24}\gamma e^4 + \frac{37}{1536}\gamma e^6 + \frac{1}{32}\gamma^3 e^2\right].$$

$$\sin(g+4l)\left[+\frac{8}{3}\gamma e^3 - \frac{14}{3}\gamma e^5\right].$$

$$\sin(g-2l)\left[-\frac{1}{6}\gamma e^3 + \frac{1}{24}\gamma e^5\right].$$

$$\sin(g+5l)\left[+\frac{625}{192}\gamma e^4 - \frac{625}{96}\gamma e^6\right].$$

$$\sin(g-3l)\left[-\frac{9}{64}\gamma e^4 + \frac{9}{160}\gamma e^6\right].$$

$$\sin(g+6l)\left[+\frac{81}{20}\gamma e^5\right].$$

$$\sin(g-4l)\left[-\frac{2}{15}\gamma e^5\right].$$

$$\sin(g+7l)\left[+\frac{117649}{23040}\gamma e^6\right].$$

$$\sin(g-5l)\left[-\frac{625}{4608}\gamma e^6\right].$$

$$\sin(3g+3l)\left[-\frac{1}{3}\gamma^3 - \frac{1}{4}\gamma^5 + 3\gamma^3 e^2 - \frac{405}{64}\gamma^3 e^4 + \frac{9}{4}\gamma^5 e^2 - \frac{3}{8}\gamma^7\right].$$

$$\sin(3g+4l)\left[-\gamma^3 e - \frac{3}{4}\gamma^5 e + \frac{13}{2}\gamma^3 e^3\right].$$

$$\sin(3g+2l)\left[+\gamma^3 e + \frac{3}{4}\gamma^5 e - \frac{11}{4}\gamma^3 e^3\right].$$

$$\sin(3g+5l)\left[-\frac{17}{8}\gamma^3 e^2 + \frac{593}{48}\gamma^3 e^4 - \frac{51}{32}\gamma^5 e^2\right].$$

$$\sin(3g+l)\left[-\frac{7}{8}\gamma^3 e^2 + \frac{31}{48}\gamma^3 e^4 - \frac{21}{32}\gamma^5 e^2\right].$$

$$\sin(3g+6l)\left[-\frac{47}{12}\gamma^3 e^3\right].$$

$$\sin 3g\left[+\frac{1}{6}\gamma^3 e^3\right].$$

$$\sin(3g+7l)\left[-\frac{2567}{384}\gamma^3 e^4\right]$$

$$\sin(3g-l)\left[+\frac{5}{384}\gamma^3 e^4\right].$$

$$\sin(5g+5l)\left[+\frac{3}{20}\gamma^5+\frac{1}{4}\gamma^7-\frac{15}{4}\gamma^5e^2\right].$$

$$\sin(5g+6l)\left[+\frac{3}{4}\gamma^5e\right].$$

$$\sin(5g+4l)\left[-\frac{3}{4}\gamma^5e\right].$$

$$\sin(5g+7l)\left[+\frac{75}{32}\gamma^5e^2\right].$$

$$\sin(5g+3l)\left[+\frac{45}{32}\gamma^5e^2\right].$$

$$\sin(7g+7l)\left[-\frac{5}{56}\gamma^7\right].$$

On the Determination of Positions of Stars for the Astrographic Catalogue at the Royal Observatory, Greenwich. By W. H. M. Christie, M.A., F.R.S., and F. W. Dyson, M.A.

Systematic measurement of the plates taken at the Royal Observatory for the Astrographic Catalogue was commenced in 1894 October. The measures were made with a glass scale in the focal plane of the viewing microscope, and since 1895 January the duplex micrometer has been almost exclusively used. A brief description of the glass scale and of the essential features of the duplex micrometer is given in the report of the Council of the R.A.S. [*Monthly Notices*, vol. lv. p. 206.] It may be mentioned that the plates, whether for the Chart or for the Catalogue, or for other objects, are all numbered consecutively in the order in which they are taken.

The coordinates of both the 6^m and 3^m images were measured, and the means were taken and used as the star's coordinates on the plate in subsequent reductions. When the images were sensibly circular the mean radius was measured; when elliptical, the greatest and least radii.

Thirty overlapping quarter-plates have been connected and compared with one another, all the stars common to the two plates being used. The stars whose places are given in the catalogues of the Astronomische Gesellschaft have been compared with the measured places on *seventy-two* plates. In both cases the linear method of reduction proposed by Professor Turner has been employed.

The chief points considered in this paper are —

1. The arrangement of the measures.
2. Connection of overlapping plates.
   (*a*) Mean discordances in the measures on overlapping plates, and

(*b*) Probable error of the relative constants.
(*c*) Systematic error in the relative constants.

3. Comparison with the Zone Catalogues of the Astronomische Gesellschaft.

(*a*) Method of forming standard coordinates.
(*b*) Mean discordances between the measures and the catalogue places, and
(*c*) Probable errors of the absolute plate constants.
(*d*) Errors of the catalogues employed.

1. *Arrangement of the Measures.*

By a resolution of the Congress the whole sky is to be completely covered by two sets of photographs. Roughly speaking, the corners of one set of plates are at the centres of the other set. In order to make sure of taking the whole of the sky, the plates overlap one another to some extent, so that while every star appears on at least two plates, some may occur on three, four, or five plates. The diagram illustrates the arrangement of these plates, though the inclinations are exaggerated for the sake of clearness. A star near the centre of A would be shown as well on the right-hand bottom corner of B, the left-hand bottom corner of C, and on the top right and left-hand corners respectively of two plates in a lower zone. There seems no object in giving some stars more than twice, while by far the greatest number are given only twice, but it is desirable to place together the measures of the same stars on the two plates. The duplex micrometer lends itself to this object. In the

Diagram I.

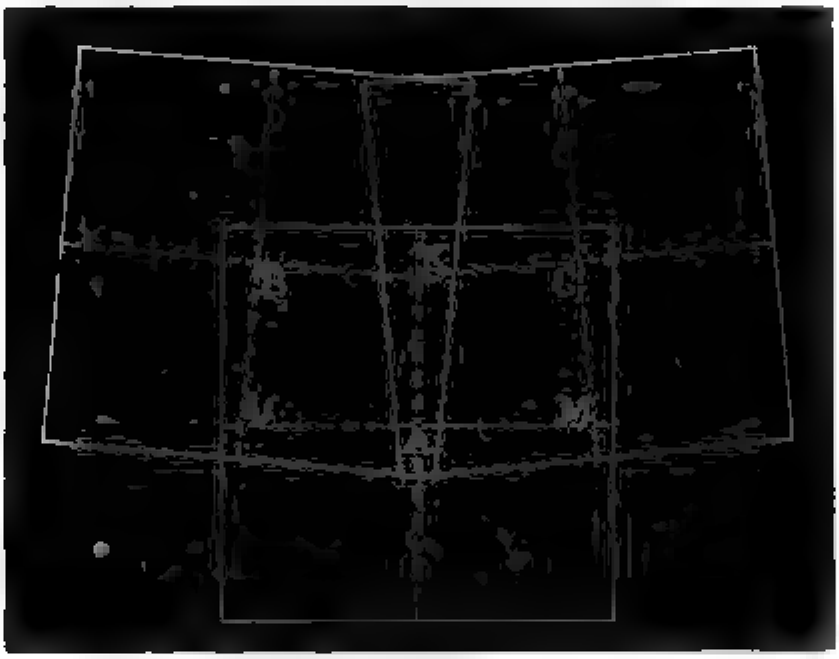


Diagram I., A, B, C are the centres of the three plates; AK, LAM, BL, BK, and CM, CK are the central *réseau* lines;

AK, BL, and CM being the projections of meridians on the respective plates, and LAM, BK, and CK the projections of great circles perpendicular to these meridians. When the two plates A and B are being measured in the duplex micrometer, the same star on the two plates is simultaneously under the two microscopes, and if the area measured is confined to that bounded by the central *réseau* lines of the two plates—that is, the area BLAK—and the same rule is adhered to with each pair of plates measured, then the whole sky will be divided into areas such as BLAK, KAMC, and the position of each star will be measured on two plates, and on two only, and the measures of the same star are automatically brought together.

Diagram II. shows into what portions the sky will be divided. A, B, C, K, L, M, correspond to the same letters in Diagram I. D is the centre of an adjacent plate in the same zone as A, E the centre of a third plate in the same zone as C and B.

Diagram II.

A modification of this method is necessary in what are called the transition zones, *i.e.* consecutive zones in which the number of plates per zone is changed. The same principle may be applied, however, and it is only necessary to substitute some other *réseau* lines instead of the central meridianal ones as the boundaries of the measures. If the same line on A is used when A is measured with B as when A is measured with C, the whole sky will be covered.

The measures are entered in the following form, the plates whose centres are at the smaller declination being placed on the left-hand side of the page :—

Zone +65°.

Plate 2270, R.A. 19^h 57^m. Plate 2290, R.A. 19^h 48^m.

No.	Radii.	x_1		y_1		x_1-x_2	y_1-y_2	Radii.	x_2		y_2	
18	0·5	11·936	6	15·454	2	...	...	1·5 0·5	20·550	0	4·834	5
	0·3	6	5	·385	2	...	...	1·4 0·4	·46	7	·765	5
		11·9356		15·4185		−8·3873	10·6184		20·5483		4·7999	

After the measures common to these plates follow those common to Plate 2270, R.A. 19^h 57^m, and Plate 2338, R.A. 20^h 6^m.

The readings on the glass scale of the two *réseau* lines between which the star is contained are given on the same horizontal line; the measures of the 3^m images are placed under those of the 6^m images, and the mean includes the correction for runs. The unit for the coordinates x and y is one *réseau*-interval $=5'$, and for the radii 1 div. of glass scale $=0·01$ *réseau*-interval $=3''$.

2. *Comparison of Plates inter se.*

4. In a paper published in the *Monthly Notices*, 1894 December, the results of a comparison of the measures of stars on four plates were given, the four plates being so arranged that each covered part of the sky covered by two of the others.

Since then the measures on twenty overlapping plates have been compared, the means of the measures of the 6^m and 3^m exposures being used. For convenience the notation may be again explained.

x_1, y_1 are the star's measured coordinates on one plate.

x_{12}, y_{12}, are coordinates obtained from these by a theoretical transformation which would accurately give the star's coordinates on the second plate if the plates had no errors of setting, &c., and such errors as refraction, &c. were all corrected.

x_2, y_2, are the star's measured coordinates on the second plate.

a, b, c, d, e, f, are constants obtained by the solution of equations of the form

$$x_2 - x_{12} = ax_2 + by_2 + c$$

$$y_2 - y_{12} = dx_2 + ey_2 + f$$

that is to say, by a comparison of all the measures on the two plates.

It is unnecessary to give any details of the arithmetical methods employed to minimise the labour of obtaining x_{12}, y_{12}, from x_1, y_1, and the relative constants a, b, c, d, e, f. Practically they are identical with those given by Professor Turner (*Monthly Notices*, Vol. LV. p. 102), the only differences worth mentioning being that another figure has been used throughout the computations, and that the correction for the small square terms was taken from a table instead of from a diagram.

With these constants the corrections $ax + by + c$, $dx + ey + f$ have been computed for several plates, and the residuals

$$x_2 - x_{12} - ax_2 - by_2 - c$$
$$y_2 - y_{12} - dx_2 - ey_2 - f$$

have been formed.

The results obtained are—

Nos. of Plates.	No. of Stars.	Mean Discordances x Coor.	Mean Discordances y Coor.
		$''$	$''$
1274–443	40	±·51	±·66
534–444	128	±·45	±·45
1274–444	44	±·63	±·39
2290–2270	28	±·45	±·57
2251–1397	34	±·33	±·33
2251–2306	28	±·39	±·36
2251–2290	50	±·39	±·36
Mean	...	±·45	±·44

Thus the mean error of a position on one plate is $\pm 0''{\cdot}31$, giving a probable error $\pm 0''{\cdot}27$.

The Probable Errors of the Relative Constants a, b, c, d, e, f.

The values of the constants a, b, c, are obtained by solving equations of the form

$$ax + by + c = \alpha.$$

Instead of solving these equations by least squares, practically as good results are obtained by taking the mean of the stars on the top half, and the mean on the bottom half to determine b, and similarly by comparing the means for the right and left halves of the plate to determine a.

If there are n stars fairly uniformly distributed over the quarter plate, we have four equations approximating to

$$\left.\begin{aligned}
\frac{n}{2}\left\{c+6a+9b\right\} &= \alpha_1\\
\frac{n}{2}\left\{c+6a+3b\right\} &= \alpha_2\\
\frac{n}{2}\left\{c+3a+6b\right\} &= \alpha_3\\
\text{and}\qquad \frac{n}{2}\left\{c+9a+6b\right\} &= \alpha_4
\end{aligned}\right\}$$

where $\alpha_1+\alpha_2=\alpha_3+\alpha_4$.

Let

ϵ = mean discordance between the measures of one star on the two plates.

Then

$\epsilon\times\sqrt{\frac{n}{2}}\times\cdot85$ = probable error of right-hand side of the above equations,

and we find

$$\left.\begin{aligned}
c+6a+6b &= \frac{\alpha_1+\alpha_2}{n}, \text{ with probable error } \frac{\epsilon}{\sqrt{n}}\times\cdot85\\
6a &= \frac{\alpha_4-\alpha_3}{n} \qquad ,, \qquad ,, \qquad \frac{2\epsilon}{\sqrt{n}}\times\cdot85\\
6b &= \frac{\alpha_1-\alpha_2}{n} \qquad ,, \qquad ,, \qquad \frac{2\epsilon}{\sqrt{n}}\times\cdot85
\end{aligned}\right\}$$

Therefore the probable errors of a, b, c, are

$$\frac{\epsilon}{3\sqrt{n}}\times\cdot85,\qquad \frac{\epsilon}{3\sqrt{n}}\times\cdot85,\qquad \frac{3\epsilon}{\sqrt{n}}\times\cdot85$$

respectively.

Taking

$$n=49, \text{ and } \epsilon = \pm\overset{\text{int.}}{0{\cdot}0015} = \pm0''{\cdot}45$$

these give probable errors

for a and b $\pm\cdot0006$, and

for c $\pm0''{\cdot}16$.

These are based on the supposition that the stars are uniformly distributed about the centre of the quarter plate. If this is not the case, these errors will be larger. From actual computation the errors of the relative constants have been found to be as follows:—

Nos. of Plates.	Probable Errors of relative constants. *a*.	*b*.	*c*.	*d*.	*e*.	*f*.
1274–443	·00008	·00006	0″·16	·00011	·00007	0″·21
534–444	·00004	·00007	·15	·00004	·00007	·15
1274–444	·00008	·00010	·21	·00007	·00009	·13
2290–2270	·00010	·000 0	·28	·00011	·00011	·34
2251–1397	·00006	·00006	·18	·00006	·00006	·18
2251–2306	·00006	·00008	·21	·00007	·00009	·23
2251–2290	·00004	·00006	·23	·00004	·00006	·21

Also in the plates discussed in the *Monthly Notices* 1894 December, p. 62, where the values of the relative constants were found from two independent sets of measures, the probable error of a, b, d, e, is seen to be about ·00005, while the differences of c or f from the two sets of measures are

″·60, ″·36, ″·18, ″·78, ″·09, ″·33, ″·84, ″·06,

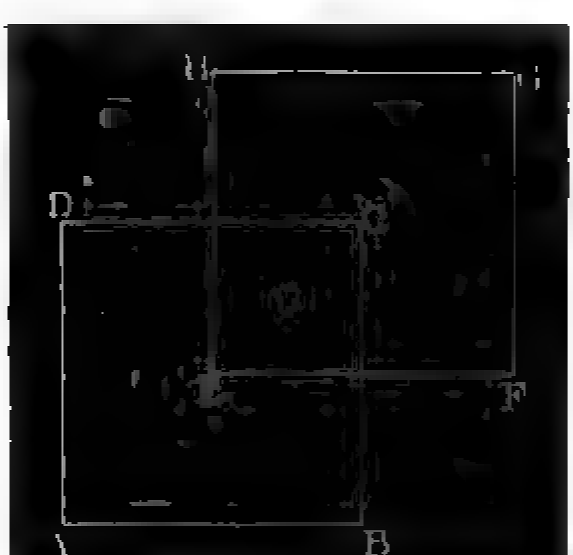
″·15, ″·12, ″·63, ″·36, ″·24, ″·45, ″·06, ″·69.

The mean of these is ″·38, giving a probable error of about ″·2 for a single determination of c or f.

We are, therefore, fairly safe in saying that with about fifty stars to a quarter plate the probable error of a, b, d, e, is about ·00007, and of c and f about ″·2.

The probable error of the correction $ax_2 + by_2 + c$, when x, y is within the quarter plate, is, in the theoretical case above discussed, between ″·05 and ″·16, or on the average about ″·10.

It seems remarkable at first sight that with fifty stars on a plate, and the probable error of a single measure $=$″·27, the probable error of c or f should be as large as ″·16, but it is evident geometrically (see diagram below) that while the position of the centre of one quarter plate with respect to that of the other is well determined (that is, points on the two plates near O), the position of the centre of one plate (C) with respect to the centre of the other (E) is, comparatively speaking, badly determined, and the position of G with respect to E is still more uncertain.



The values of the relative constants by which a plate is connected with an overlapping plate are given for thirty plates in the following table.

Values of the Relative Constants connecting 30 Overlapping Plates.

Zone.	Nos. of Plates.	No. of Stars.	a	b	c	d	e	f	$a-e$	$b+d$
66°–65°	1274–443	40	+·00008	−·00712	−·0273	+·00713	+·00002	+·0666	+·00006	+·00001
	1274–444	56	+·00034	−·00542	+·0421	+·00557	+·00021	−·0056	+·00013	+·00013
	534–444	128	+·00011	−·00249	+·0309	+·00266	+·00008	−·0305	+·00003	+·00017
	534–1236	72	+·00026	−·00154	+·0253	+·00188	−·00016	−·0015	+·00042	+·00034
	426–1236	68	−·00010	+·00035	−·0131	−·00025	−·00002	+·1975	−·00008	+·00010
	426–2290	48	−·00003	+·00167	−·0010	−·00154	−·00020	+·2958	+·00017	+·00013
	2270–2290	28	−·00035	−·00017	−·0741	+·00042	+·00013	−·0570	−·00048	+·00025
	2270–2238	44	+·00002	−·00054	−·1026	+·00026	−·00015	+·0225	+·00017	−·00028
	2280–2279	62	−·00008	−·00071	+·0174	+·00054	+·00007	+·0378	−·00015	−·00017
	2280–2308	76	−·00001	−·00031	−·0640	+·00014	+·00001	+·0843	−·00002	−·00017
	535–2308	74	−·00014	−·00033	−·0107	+·00040	−·00005	+·0011	−·00009	+·00007
66°–67°	2288–443	28	−·00019	−·00312	−·0223	+·00314	−·00019	−·1331	00000	+·00002
	2288–444	114	+·00015	−·00176	+·0080	+·00178	+·00009	−·1169	+·00006	+·00002
	2289–1236	76	−·00006	−·00131	+·0975	+·00112	−·00009	−·0549	+·00003	−·00019
	2251–2290	50	−·00010	+·00033	+·0879	−·00031	−·00013	+·0557	−·00003	+·00002
	1416–2338	64	−·00020	−·00042	+·0120	+·00028	+·00007	−·0122	−·00027	−·00002

Zone.	Nos. of Plates.	No. of Stars.	a	b	c	d	e	f	$a-e$	$b+d$
68°–67°	2288–2227	52	+·00003	−·00038	−·0618	+·00023	−·00011	−·0811	+·00014	−·00015
	2289–2227	58	−·00009	−·00039	+·0204	+·00051	−·00013	−·0548	+·00004	+·00012
	2289–1397	60	+·00014	+·00068	+·0129	−·00057	+·00008	+·0244	+·00006	+·00011
	2251–1397	34	−·00019	+·00097	−·0420	−·00068	+·00003	+·0112	−·00016	+·00029
	2251–2306	28	−·00004	−·00087	+·0798	+·00086	−·00013	+·1100	+·00009	−·00001
	1416–2306	46	−·00024	−·00157	+·0378	+·00161	−·00008	+·0032	−·00016	+·00004
68°–69°	1323–2227	96	−·00023	+·00200	−·0139	−·00202	−·00017	−·0104	−·00006	−·00002
	1323–1397	90	−·00010	+·00318	+·0075	−·00307	−·00016	+·0773	+·00006	+·00011
	2291–1397	46	−·00014	+·00177	+·0170	−·00182	−·00014	+·0134	00000	−·00005
	2291–2306	48	+·00010	+·00008	+·0911	−·00002	−·00012	+·1087	+·00022	+·00006
67°–68°	2056–2057	50	−·00030	−·00165	−·0236	+·00174	+·00000	+·1246	−·00030	+·00009
	2056–2058	52	+·00027	−·00024	+·0266	+·00037	−·00006	+·0119	+·00031	+·00013
68°–69°	2057–2059	43	+·00025	+·00116	+·0220	−·00101	+·00006	−·1016	+·00019	+·00015
	2058–2059	61	−·00008	−·00036	−·0260	+·00040	−·00003	+·0284	−·00005	+·00004
	Mean Discordance from zero	...	±·00015				±·00010		±·00013	±·00012

c and f, which are expressed in terms of the *réseau*-interval (int. $0{\cdot}1 = 30''$), arise from errors of setting of the plates.

Difference of orientation error of the two plates would be given by b and d, and for this error alone the relation $b+d=0$ should hold.

A difference of scale on the two plates would be given by a and e, and for this error alone the relation $a-e=0$ should hold. A difference in the corrections for refraction and aberration on adjacent plates would at most be 1 or 2 units in the fifth place in a, b, d, and e, and may here be treated as insensible.

The average value of a on these thirty plates is $\pm{\cdot}00015$, of $e \pm{\cdot}00010$, of $a-e \pm{\cdot}00013$. and of $b+d \pm{\cdot}00012$. Taking the probable error of a determination of a, b, d, e as $\pm{\cdot}00007$, that of $a-e$ and $b+d$ would be $\pm{\cdot}00010$, and the mean error (i.e. mean of the errors irrespective of sign) would be $\pm{\cdot}00012$, which agrees exactly with the value of the mean discordance found above. This table seems, therefore, to show that the differences of $a-e$ and $b+d$ from zero are accidental.

To test further the accidental nature of the differences $a-e$ and $b+d$, the plates showing the largest values of these quantities in the above table (Plates 2290 and 2270) were connected on the two hypotheses :—(1) that the differences $a-e$ and $b+d$ were real ; (2) that they were accidental, and that

$$a=e=\frac{a+e}{2} \text{ and } b=-d=\frac{b-d}{2}$$

and the discordances were formed. The mean discordance is slightly increased, there being in the second case only four quantities at disposal instead of six, but so slightly that the introduction of two arbitrary corrections for which no physical reason is given does not seem to be justified. The discordances found by the two methods are given in the following table.

Comparison of Plates 2290 and 2270 on two Hypotheses.

Coordinates on Plate 2270.		Discordances in x Coor.		Discordances in y Coor.	
		(1) a, e, b, d independ.	(2) $a=e$ $b=-d$	(1) a, e, b, d independ.	(2) $a=e$ $b=-d$
x	y				
1·90	21·91	+ ·0005	+ ·0019	+ ·0000	− ·0005
1·77	16·43	+ 18	+ 27	− 30	− 49
3·35	22·37	+ 5	+ 16	+ 22	+ 21
3·46	22·21	− 2	+ 17	− 26	− 27
4·17	16·68	+ 10	+ 10	− 6	− 16
4·19	20·90	− 1	+ 6	+ 15	+ 11
4·13	21·38	− 10	− 3	+ 1	− 6
5·65	17·44	− 9	− 8	+ 60	+ 49
5·63	20·02	+ 19	+ 21	+ 17	+ 22
6·49	23·38	− 30	− 27	+ 8	+ 13
6·16	21·97	+ 24	+ 27	− 34	− 33
7·07	16·39	+ 23	+ 14	+ 3	− 8
7·56	17·29	− 37	− 45	− 24	− 33
7·65	17·34	− 24	− 20	− 5	− 15
7·96	23·45	+ 27	+ 26	+ 4	+ 22
8·93	26·33	+ 3	+ 5	− 26	− 11
8·90	17·00	+ 15	+ 4	− 35	− 43
9·15	16·71	+ 3	+ 2	− 7	− 15
9·54	19·83	− 11	− 18	− 38	− 38
10·32	22·52	− 3	− 10	+ 28	+ 34
10·04	20·32	− 6	− 27	+ 23	+ 25
10·06	18·50	+ 16	+ 5	+ 8	+ 5
10·82	16·66	+ 31	+ 13	− 13	− 19
11·04	20·66	− 28	− 40	+ 3	+ 6
11·41	20·33	+ 3	+ 10	+ 13	+ 17
11·15	23·66	− 19	− 27	+ 12	+ 25
11·98	26·29	+ 8	+ 1	+ 43	+ 62
13·45	25·91	− 19	− 30	− 16	+ 1
Mean discordance	...	± ·0015	± ·0017	± ·0019	± ·0023

Systematic Error in the Determination of a.

In the two following tables the relative constants a, e, and $b+d$ are given, according as they refer respectively to plates in which a *S.E. and* N.W. quarter correspond or a S.W. and N.E. quarter :—

Relative Constants found by transforming from S.E. to N.W.

Zones.	Nos. of Plates.	a	e	b+d
66°–65°	443–1274	−·00008	−·00002	−·00001
	444–534	−·00011	−·00008	−·00017
	1236–426	+·00010	+·00002	−·00010
	2290–2270	+·00035	−·00013	−·00025
	2279–2280	+·00008	−·00007	+·00017
	2308–535	+·00014	+·00005	+·00007
	Means ...	+·00008	−·00005	−·00005
68°–67°	2227–2289	+·00009	+·00013	−·00012
	1397–2251	+·00019	−·00003	−·00029
	2306–1416	+·00024	+·00008	−·00004
	Means ...	+·00017	+·00006	−·00015
69°–68°	1323–1397	−·00010	−·00016	−·00001
	2291–2306	+·00010	−·00012	+·00006
	Means ...	·00000	−·00014	+·00002
	2056–2058	+·00027	+·00066	+·00013
	2057–2059	+·00025	+·00006	+·00015

Relative Constants found by transforming from S.W. to N.E.

Zones.	Nos. of Plates.	a	e	b+d
66°–65°	444–1274	−·00034	−·00021	−·00013
	1236–534	−·00026	+·00016	−·00034
	2290–426	+·00003	+·00020	−·00013
	2338–2270	−·00002	+·00015	+·00028
	2308–2280	+·00001	−·00001	+·00017
	Means ...	−·00012	+·00006	−·00003
68°–67°	2227–2288	−·00003	+·00011	+·00015
	1397–2289	−·00014	−·00008	−·00011
	2306–2251	+·00004	+·00013	+·00001
	Means ...	−·00004	+·00005	+·00002

69°–68°	1323–2227	−·00023	−·00017	−·00002
	2291–1397	−·00014	−·00014	−·00005
	Means ...	−·00018	−·00015	−·00003
	2056–2057	−·00030	00000	+·00009
	2058–2059	−·00008	−·00003	+·00004

The values of a in the first table are nearly all positive, while those in the second are nearly all negative. This systematic error is shown more distinctly if an overlapping plate is used to connect two plates in the same zone. We thus obtain the following table:—

Zone.	Nos. of Plates.	Difference of a.	Means.
65°	1274–534	+·00023	+·00026
	534–426	+·00036	
	426–2270	+·00032	
	2280–535	+·00013	
66°	443–444	+·00026	+·00019
		+·00034	
	444–1236	+·00015	
	1236–2290	+·00007	
	2290–2238	+·00037	
	2279–2308	+·00007	
67°	2288–2289	+·00012	+·00019
	2289–2251	+·00024	
	2251–1416	+·00020	
68°	2136–2227	+·00039	+·00029
	2227–1397	+·00023	
		+·00013	
	1397–2305	+·00006	
		+·00024	
	2058–2057	+·00045	
69°	1323–2291	+·00004	+·00004

The mean of these differences is +·00021. The explanation of this systematic error has not been investigated. It may perhaps be due to a systematic difference in division errors of the *réseau*, or in optical distortion between the east and west halves of the *plate. Its existence*, however, shows that it would be impossible

to step along a zone connecting one plate with another by means of intermediary overlapping plates without introducing a large and uncertain correction for this unexplained error, which is cumulative in its effect.

3. *Comparison of the Measured Coordinates of the Stars with the Places given in the Catalogues of the Astronomische Gesellschaft.*

The places given in the Helsingfors-Gotha (60°–65°) and Christiania (65°–70°) Catalogues were brought up to the epoch 1900·0. The standard coordinates ξ, η are obtained from the Right Ascensions and North Polar distances by the formulæ

$$\left.\begin{aligned} \xi &= \tan(\alpha - A) \cdot \sin q \cdot \sec(P - q) \quad . \quad . \quad (1) \\ \eta &= \tan(P - q) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2) \\ \text{where } \tan q &= \tan p \cdot \cos(\alpha - A) \quad . \quad . \quad . \quad . \quad . \quad . \quad (3) \end{aligned}\right\} \textit{M.N.}\text{ vol. liv. p. 17.}$$

To avoid the use of tables of logarithmic sines and cosines computed for every second of arc, to save the conversion of time into arc, and generally to diminish the labour of computation, these formulæ were further transformed. (See *Observatory*, vol. XVIII. pp. 328, 329, 351–355.)

From the third of the above formulæ

$$q = p + \frac{\cos(\alpha - A) - 1}{\cos(\alpha - A) + 1} \sin 2p + \tfrac{1}{2} \cdot \left(\frac{\cos(\alpha - A) - 1}{\cos(\alpha - A) + 1}\right)^2 \sin 4p + \&c. \quad . \quad . \quad . \quad (4)$$

Using declination (δ) instead of north polar distance (p) and putting D for the declination of the centre of the plate, we have from (2) and (4)

$$\tan^{-1}\eta = \delta - D + \tan^2 \frac{\alpha - A}{2} \sin 2\delta + \&c.$$

Therefore

$$\eta = \delta - D + \tan^2 \frac{\alpha - A}{2} \sin 2\delta + \&c. + (\eta - \tan^{-1}\eta) \quad . \quad . \quad . \quad . \quad (5)$$

Again, the above formulæ give

$$\xi = (\sin P - \eta \cos P) \cdot \tan(\alpha - A),$$

ξ and η being supposed expressed in circular measure, or

$$\xi = \left(\frac{2160}{\pi} \tan P - \eta\right) \cdot \cos P \cdot \tan(\alpha - A) \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

when ξ and η are expressed in *réseau* intervals (1 *réseau* interval $= 5'$).

From (6) we obtain

$$\log \xi = \log \left\{ \left(\frac{2160}{\pi} \tan P - \eta\right) \cdot \cos P \right\} + \log(\alpha - A)$$
$$+ \log \frac{\tan(\alpha - A)}{(\alpha - A)}$$

($\alpha - A$ being expressed in circular measure).

Now

$$\log \frac{\tan(\alpha - A)}{\alpha - A} = \log\left[1 + \frac{(\alpha - A)^2}{3}\right]$$

and

$$\log \sec(\alpha - A) = \log\left[1 + \frac{(\alpha - A)^2}{2}\right]$$

Therefore

$$\log \frac{\tan(\alpha - A)}{\alpha - A} = \tfrac{2}{3} \log \sec(\alpha - A).$$

Thus we obtain (when $\alpha - A$ is expressed in seconds of time)

$$\log \xi = \log(\alpha - A) + \log\left\{\left(\frac{2160}{\pi}\tan P - \eta\right) . \cos P . \sin 15''\right\} + \tfrac{2}{3}\log \sec(\alpha - A) \quad . \quad . \quad . \quad . \quad (7)$$

and formula (5) becomes

$$\eta = \delta - D + \frac{2160}{\pi}\tan^2\frac{\alpha - A}{2} . \sin 2\delta + \frac{2160}{\pi}(\eta - \tan^{-1}\eta) \quad . \quad . \quad . \quad (8)$$

These formulæ give ξ and η expressed in *réseau* intervals, the term $\delta - D$, being converted from arc to these units, by means of a small table similar to the table used for converting time into arc.

Tables are formed to give

$\delta - D$ in *réseau* intervals	arg $(\delta - D)$	Table IV.
$\frac{2160}{\pi}\tan^2\frac{\alpha - A}{2}$ and $\frac{2}{3}\log\sec(\alpha - A)$ . . .	arg $(\alpha - A)$ {in seconds of time.}	Table III.
$\sin 2\delta$	arg δ	Table II.
$\frac{2160}{\pi}(\eta - \tan^{-1}\eta)$	arg η	Table V.
$\log\left\{\left(\frac{2160}{\pi}\tan P - \eta\right)\cos P . \sin 15''\right\}$	arg η	Table I.

All the tables except Table I. are available for all zones; Tables IV. and V. are very small; and they are all very quickly computed from ordinary trigonometrical tables.

As the numbering of the *réseau* lines is such that the central line is called 14, the tables have been computed in accordance with this notation. The multiplication of $\frac{2160}{\pi}\tan^2\frac{\alpha - A}{2}$ and $\sin 2\delta$ is performed by use of Crelle's tables. Log $(\alpha - A)$ is obtained from ordinary logarithm tables without any interpolation being necessary. The numerical work is carried to four places of decimals (the unit being 5′) so that the last figure ·0001 is *equal to 0″·03.*

The following is the form employed in the computation :—

α = R.A. of star for 1900·0 A = R.A. of centre for 1900·0	δ – Decl. of star for 1900·0 D = Decl. of centre for 1900·0
α – A	Table IV. Arg. δ
Log (α – A) Table III. (1) arg (α – A) Table I. arg η	Table II. } Product Table III. (2) } Table V. η = Sum
Sum	
Corr. No. Corr. No. + 14 = ξ	

The standard coordinates thus found are compared with the measures, and equations

$$\left.\begin{aligned} ax + by + c &= \xi - x \\ dx + ey + f &= \eta - y \end{aligned}\right\}$$

written down for each star on the plate considered which is contained in the Catalogue. The values of the absolute constants a, b, c, d, e, f are deduced in the same way as in the case of the relative constants. These being determined, the "standard coordinates" of a star whose measured coordinates are x and y are

$$x + ax + by + c$$
$$y + dx + ey + f.$$

These absolute constants have been determined for 72 plates in the zones 65°, 66°, and 67°, and the corrections applied to those stars which are given in the Catalogues. The standard coordinates ξ, η thus found are compared with those deduced from the Catalogue, which may now be called ξ_0, η_0. The following table of these constants a, b, c, &c., for 10 plates in zone 66° is given as a specimen.

Absolute Plate Constants. Zone 66°.

No. of Plate.	No. of Stars.	a	b	c	d	e	f	$a-e$	$b+d$
2521	14	–·00062	+·00090	–·0177	–·00098	–·00088	+·1138	+·00026	–·00008
940	18	–·00083	+·00058	–·1635	–·00095	–·00062	+·0856	–·00021	–·00037
941	12	–·00027	+·00067	–·1671	–·00069	–·00071	+·1064	+·00044	–·00002
942	19	–·00060	+·00080	–·0121	–·00060	–·00090	+·1028	+·00030	+·00020
2526	17	–·00082	+·00351	–·0404	–·00380	–·00076	+·1856	–·00006	–·00029
2537	17	–·00069	+·00081	–·0279	–·00083	–·00071	+·1088	+·00002	–·00001
962	21	–·00075	+·00055	–·1755	–·00042	–·00051	+·0838	–·00024	+·00013
2557	22	–·00072	+·00052	–·0536	–·00052	–·00046	+·1014	–·00026	·00000
2593	21	–·00069	+·00061	–·0235	–·00072	–·00078	+·1145	+·00009	–·00011
2559	23	–·00089	+·00122	–·0464	–·00139	–·00054	+·1197	–·000035	–·00017

The average values of the discordances $\xi-\xi_0$, $\eta-\eta_0$ are given below for 24 plates, with the number of Catalogue stars on each plate.

No. of Plate.	Number of Stars.	Mean discordance. $\xi-\xi_0$	$\eta-\eta_0$	No. of Plate.	Number of Stars.	Mean discordance. $\xi-\xi_0$	$\eta-\eta_0$
		$''$	$''$			$''$	$''$
1274	31	±0·75	±0·81	2521	14	±0·96	±0·93
534	40	±0·51	±0·90	940	18	±0·73	±0·93
2288	35	±0·63	±0·99	941	12	±0·77	±0·63
1323	23	±0·57	±0·93	942	19	±0·72	±0·90
443	32	±0·63	±0·69	2526	17	±0·78	±0·96
444	46	±0·51	±0·69	2537	17	±1·12	±0·56
2251	34	±0·68	±0·99	962	21	±1·05	±0·88
331*a*	30	±0·96	±0·99	2557	22	±0·93	±1·02
2522	12	±0·77	±1·19	2593	21	±0·75	±0·81
336	20	±0·72	±0·78	2559	23	±1·11	±0·81
2022	28	±0·96	±0·80	2560	30	±0·54	±0·81
345	24	±0·62	±0·72	2654	26	±0·96	±0·99

Thus the average discordances for $\xi-\xi_0$ and $\eta-\eta_0$ are $\pm0''.76$ and $\pm0''\cdot86$, and the probable errors of these differences $\pm0''\cdot65$ and $\pm0''\cdot71$.

The probable errors of the absolute plate constants *a*, *b*, *c*, *d*, *e*, *f*, have been deduced in a few cases with the following results:—

No. of Plate.	No. of Stars.	Probable Error of *a*	*b*	*c*	*d*	*e*	*f*
331*a*	30	±·00007	±·00011	±0·19	±·00011	±·00007	±0·18
2522	12	±·00008	±·00010	±0.30	±·00006	±·00013	±0·21
336	20	±·00005	±·00008	±0·14	±·00007	±·00007	±0·16
443	32	±·00008	±·00007	$\pm0''\cdot14$	±·00006	±·00009	$\pm0''\cdot15$
2251	34	±·00005	±·00006	±0·12	±·00007	±·00008	±0·15
1274	31	±·00010	±·00009	±0·11	±·00009	±·00011	±0·14
2521	14	±·00014	±·00015	±0·28	±·00014	±·00015	±0·27
940	18	±·00018	±·00017	±0·18	±·00010	±·00019	±0·24
941	12	±·00007	±·00006	±0·13	±·00008	±·00007	±0·17
942	19	±·00009	±·00009	±0·18	±·00011	±·00011	±0·22
2526	17	±·00012	±·00012	±0·16	±·00014	±·00014	±0·20
Mean		±·00009	±·00009	±0·18	±·00010	±·00010	±0·19

We may take the probable error of the constants *a*, *b*, *d*, *e* as about ±·00010, and the mean error as ±·00012.

The constants *a*, *b*, *c*, *d*, *e*, *f*, thus determined by direct comparison of the plates and the Catalogue, contain the corrections

for refraction, aberration, orientation of the plate and value of the scale. In zones 65°, 66°, and 67°, the refraction produces −·00028 in a and −·00030 in e, and the variations from these are less than ·00001 when the plates are taken within an hour of the meridian. The effect of refraction on b and d is at most one or two units in the fifth place. The correction for aberration is the same in a and e, and, roughly speaking, may vary from +·00003 to −·00005.

When the constants are corrected for aberration, we obtain the following values for $\frac{a+e}{2}$:—

−·00062	from 11 plates in zone	65°		
−·00072	„	11 „ „	65	
−·00066	„	10 „ „	65	
−·00064	„	12 „ „	66	
−·00072	„	11 „ „	66	

The mean of these is −·00067; adding −·00029 for refraction, we find the scale correction = −·00096.

The following table exhibits the value of $\frac{a+e}{2}$ (after correction for aberration) on plates taken on the same nights, together with the temperature of the tube :—

No. of Plate.	When taken.	Temp. of Tube.	$\frac{a+e}{2}$	Mean value for the night.
861	1893 Mar. 17	41°·0	−·00056	
862	„	„	−·00048	−·00063
863	„	„	−·00084	
940	1893 Mar. 29	48·3	−·00067	
941	„	47·6	−·00045	−·00061
942	„	„	−·00071	
2521	1895 Apr. 10	54·0	−·00070	
2522	„	53·5	−·00063	
2524	„	53·0	−·00081	−·00074
2525	„	„	−·00080	
2526	„	„	−·00075	
2554	1895 Apr. 23	50·0	−·00057	
2555	„	49·7	−·00065	
2557	„	49·1	−·00058	−·00063
2559	„	49·0	−·00069	
2560	„	„	−·00067	

2568	1895 Apr. 24	51·0	−·00046	
2569	"	50·0	−·00068	−·00056
2570	"	50·0	−·00055	
2044	1894 May 17	53·8	−·00097	
2046	"	52·9	−·00065	−·00069
2048	"	51·3	−·00044	

Examination of this table, as far as it goes, shows that the change in $\frac{a+e}{2}$ is due to accidental errors in the measures and assumed places of the stars, and not to real changes in the scale of the plate.

The following table gives the average values of the discordances of a, e, and $\frac{a+e}{2}$ (corrected for aberration) from the mean value, and of $a-e$ and $b+d$ from zero:—

Zone.	Number of Plates.	Discordances from Mean.			Discordances from Zero.	
		a	e	$\frac{a+e}{2}$	$a-e$	$b+d$
65°	11	±·000130	±·000189	±·000127	±·000212	+·000262
65	11	±·000164	±·000183	±·000105	±·000198	±·000261
65	10	±·000114	±·000097	±·000093	±·000153	±·000168
66	12	±·000123	±·000100	±·000073	±·000210	±·000163
67	11	±·000163	±·000136	±·000143	±·000149	±·000271
Mean	55	±·000139	±·000141	±·000108	±·000184	±·000225

There does not seem to be any physical reason why $a-e$ and $b+d$ should differ from zero, at any rate by more than one or two figures in the fifth place. Remembering this, and comparing the above table with the mean error previously found for a, e, b, and d—viz. ±·00012, which would give ±·00017 as the mean error of $a-e$, or $b+d$, we conclude that these discordances are mainly due to accidental errors in the measured coordinates of the stars and of the assumed right ascensions and declinations. It therefore seems that by adopting a constant value for the scale, and assuming that the conditions $a-e=0$ and $b+d=0$ hold, better values of the plate constants will be obtained. When the correction for aberration is not separately applied, the values

$$a=e=-\cdot00070$$

and

$$b=-d=\frac{b-d}{2}$$

differ but slightly from the true values, and it is proposed to adopt these values in the formation of residuals from which final

corrections to the plate constants may be deduced. The values adopted for a and e include a mean correction of $-\cdot 00029$ for refraction, and the variations in the corrections for refraction and aberration, which are very small, would be applied subsequently when the final corrections to the plate constants are determined.

In reference to the large differences between the measures and the Catalogue places, the following comparison of the places of stars common to the two Catalogues in the overlapping zone 64° 50′ and 65° 10′ is of interest :—

Comparison of the Christiania (64° 50′–70° 10′) *and Helsingfors-Gotha* (54° 50′–65° 10′) *Catalogues.*

R.A.	Number of Stars.	Mean Discordance R.A.	Mean Discordance Dec.	Mean Difference of Declination Hel.-Chr.
h h		s	″	″
0–2	35	±·125	±0·98	+·15
2–4	24	±·098	±1·51	+·85
4–6	24	±·135	±1·32	+·44
6–8	26	±·168	±1·07	+·50
8–10	28	±·104	±0·74	+·18
10–12	29	±·132	±1·15	+·26
12–14	25	±·084	±0·88	·00
14–16	23	±·120	±0·94	+·44
16–18	25	±·108	±1·27	+·87
18–20	39	±·124	±1·25	+·85
20–22	45	±·090	±0·89	+·41
22–24	34	±·123	±1·05	+·94
	357	±·123	±1·08	+·49

Including the systematic difference between the declinations of the two Catalogues in the accidental error, the mean discordances between them are $\pm 0^{s}\cdot 123$ in R.A., and $1''\cdot 08$ in Declination or expressing them both in arc, the probable errors of the differences are $\pm 0''\cdot 58$ and $\pm 0''\cdot 92$.

Of the plates taken for the Astrographic Catalogue at the Royal Observatory, about 130 have already been measured. The present rate of progress, now that an adequate staff has been organised under Mr. Hollis and a fixed routine adopted, is about 180 a year, 46 having been measured between October 1 and December 31, so that five or six years will be required to measure

all the plates. The parts of the sky already measured on pairs of overlapping plates are :—

	° °	h m h m	h m h m
Decl.	65–66	R.A. 11 15– 1 21	
„	66–67	R.A. 11 24– 0 0	
„	67–68	R.A. 11 30– 0 0,	except 22 10–22 30
„	68–69	R.A. 19 0–20 0	

Comparison of the measures with the right ascensions and declinations of the Helsingfors-Gotha or Christiania Catalogues, and determinations of plate constants, have been made for 72 plates; the whole of this work having been done under the superintendence of Mr. Hollis. About 40 of these determinations have been made between October 1 and December 31, or at the rate of 160 plates a year.

Observations of Comet d 1895 (Brooks) made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1895. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Dec. 15 10 36 21	A. C.	+1 27·85	+0·01	9·6430	−3 51·3	−0·1	0·0776	6	6 20 30·98	25 58 49·1	*a*
15 10 39 4	,,	−2 1·58	−0·01	9·6350	+4 36·0	+0·1	0·0893	5	6 20 29·26	25 58 40·4	*b*

Notes.

The observations are corrected for refraction but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

The comet was a large, faint, diffused nebulosity, without nucleus, and difficult to observe.

The initials A.C. are those of Mr. Crommelin.

Comparison Stars.

	Star's Name.	Assumed R.A. 1895·0.	Assumed N.P.D. 1895·0.	Authority.
		h m s	° ′ ″	
a	B.D. + 63°, No. 647	6 18 53·72	26 2 43·7	Equatorial comparison with star *c*.
b	B.D. + 64°, No. 590	6 22 21·41	25 54 6·9	Helsingfors Gotha Ast. Gesell Catalogue.
c	O.A. (N.), 6995	6 27 55·31	26 3 51·1	,, ,, ,, ,,

Royal Observatory, Greenwich:
1896 January 7.

Observations of Occultations of Stars by the Moon and of Phenomena of Jupiter's Satellites made at the Royal Observatory, Greenwich, in the year 1895.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1895					h m	
Feb. 6	Disapp. 49 Aurigæ	Sheepshanks Equat.	100	Dark	5 48 58·99	B.
6	„ 49 Aurigæ	Altazimuth	100	„	5 48 58·52	C. D.
May 4	„ τ Leonis	Sheepshanks Equat.	120	„	7 49 40·61	H.
4	„ τ Leonis	Astrographic Guid. Tel.	120	„	7 49 40·74	C. D.
4	„ W.B. XI., 349	Sheepshanks Equat.	100	„	7 51 46·17	H.
4	„ W.B. XI., 349	Astrographic Guid. Tel.	120	„	7 51 46·20	C. D.
4	„ W.B. XI., 365	Sheepshanks Equat.	100	„	8 8 20·35	H.
4	„ W.B. XI., 365	Astrographic Guid. Tel.	120	„	8 8 20·77	C. D.
4	„ W.B. XI., 372	„ „ „	225	„	8 28 58·77	„
9	Reapp. π Scorpii	Sheepshanks Equat.	120	„	11 14 35·20	A. C.
11 (*a*)	Disapp. γ^1 Sagittarii	„ „	120	Bright	15 10 38·84	H.
June 6 (*b*)	„ τ Scorpii	Astrographic Guid. Tel.	225	„	10 43 36·25	H. F.
6 (*c*)	Reapp. τ Scorpii	„ „ „	225	„	10 58 46·85	„
26	Disapp. Regulus	Altazimuth	100	Dark	8 4 2·75	H.
26	„ Regulus	Sheepshanks Equat.	120	„	8 4 3·25	A. C.
26	Reapp. Regulus	Altazimuth	100	Bright	8 54 58·21	H.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1895.					h m s	
June 26	Reapp. Regulus	Astrographic Guid. Tel.	225	Bright	8 54 56·23	J.
July 16	„ 47 Arietis	Altazimuth	100	Dark	13 26 55·68	D.
16	„ 47 Arietis	Sheepshanks Equat.	100	„	13 26 55·17	W. B.
Aug. 6 (*d*)	Disapp. 42 Aquarii	Astrographic Guid. Tel.	225	Bright	12 25 4·06	D.E.
6	Reapp. 42 Aquarii	Sheepshanks Equat.	55	Dark	13 40 33·28	A. C.
7 (*c*)	Disapp. 81 Aquarii	Astrographic Guid. Tel.	225	Bright	13 43 19·20	J.
7	Reapp. 81 Aquarii	„ „ „	225	Dark	15 1 35·67	„
7	Disapp. 82 Aquarii	„ „ „	225	Bright	15 17 1·94	„
12	Reapp. Brad 355	Sheepshanks Equat.	100	Dark	10 0 50·41	W. B.
Sept. 2	Disapp. Aquarii	„ „	100	„	13 52 12·44	B.
2	Aquarii	Astrographic Guid. Tel.	225	„	13 52 12·14	D. E.
15	Reapp. 83 Cancri	Altazimuth	100	„	15 34 40·41	B.
29	Disapp. δ Capricorni	Sheepshanks Equat.	100	„	8 47 14·19	C. M.
29	„ δ Capricorni	Astrographic Guid. Tel.	225	„	8 47 14·18	R. C.
29 (*f*)	Reapp. δ Capricorni	Sheepshanks Equat.	100	Bright	10 7 27·01	C. M.
29	„ δ Capricorni	Astrographic Guid. Tel.	225	„	10 7 25·05	R. C.
29	„ δ Capricorni	Altazimuth	100	„	10 7 (30·67)	W.
30	Disapp. 58 Aquarii	Astrographic Guid. Tel.	225	Dark	9 9 12·48	D. E.
30	„ 58 Aquarii	Sheepshanks Equat.	100	„	9 9 12·51	J.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1895.					h m s	
Sept. 30	Disapp. 58 Aquarii	Altazimuth	100	Dark	9 9 13·38	W.
Nov. 3 (*g*)	„ 19 Tauri	Astrographic Guid. Tel.	225	Bright	13 28 29·92	H.
3	Reapp. 19 Tauri	„ „ „	225	Dark	14 45 34·81	„
3	„ 19 Tauri	Sheepshanks Equat.	55	„	14 45 34·66	A. C.
3 (*h*)	„ 20 Tauri	Astrographic Guid. Tel.	225	„	14 51 (20·47)	H.
3	„ 20 Tauri	Sheepshanks Equat.	55	„	14 51 17·62	A. C.
3 (*i*)	„ 20 Tauri	Corbett Telescope	100	„	14 51 17·29	R. C.
10	„ ψ Virginis	Altazimuth	100	„	17 29 43·11	A. C.

Notes.

The occultations during the lunar eclipse on March 10 are not included in the above table, as these have been already communicated to the Society (*M.N.* lv. 6, p. 329).

(*a*) Not considered a good observation; Moon's limb boiling; star diffused. (*b*) Observation noted as doubtful; Moon's limb boiling; cloudy. (*c*) Moon's limb ill-defined, but observation considered better than disappearance. (*d*) Not considered a good observation. (*e*) Cloudy. (*f*) Not considered a good observation; star was not quite in contact with limb when first seen. (*g*) The star was projected on the Moon's disc 1½ second before disappearance. Considered a bad observation. The count of seconds did not agree with the comparison with the clock after observation, and the observed time has therefore been increased 1^s. (*h*) The observer noted probably late; he was looking at the clock just before, and probably lost the actual reappearance. The observed time has been diminished by 1^m. (*i*) The observed time has been increased by 1^m.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1895 Jan. 9	II.	Tr. Ing.	First contact	28-inch Equat.	450	10 18 48	10 20	L.
9	II.		Last contact	,,	,,	10 22 15		,,
14	III.	Occ. D.	Last seen	Sheepsh. Equat.	55	6 45 53	6 43	H. F.
18	II.	Ecl. R.	First seen	,,	200	11 23 14		C. D.
18	II.		Bisection	,,	,,	11 25 2	11 23 58	,,
18	II.		Full brightness	,,	,,	11 26 42		,,
18	I.	Tr. Ing.	First contact	,,	100	12 52 56		,,
18	I.		Bisection	,,	,,	12 54 25	12 52	,,
18	I.		Last contact	,,	,,	12 56 50		,,
21	III.	Occ. D.	First contact	,,	200	10 2 18		A. C.
21	III.		Bisection	,,	,,	10 4 23	10 5	,,
21	III.		Last seen	,,	,,	10 8 10		,,
21	III.	Occ. R.	Last contact	,,	,,	12 52 47	12 54	,,
21	III. (a)	Ecl. D.	Began to fade	,,	,,	12 56 58	13 2 49	,,
21	III.		Last seen	,,	,,	13 2 1		,,
25	II.	Occ. D.	First contact	,,	,,	9 45 9		,,
25	II.		Bisection	,,	,,	9 47 57	9 49	,,
25	II.		Last seen	,,	,,	9 51 7		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
Jan. 28	I.	Ecl. R.	First seen	Sheepsh. Equat.	200	9 20 42	9 21	H.
28	I.		Full brightness	,,	,,	9 22 26		,,
Feb. 11	I.	Occ. D.	First contact	,,	120	9 49 47	9 52	B.
11	I.		Last seen	,,	,,	9 53 36		,,
11	I.	Ecl. R.	First seen	,,	,,	13 12 10	13 12 6	,,
19	II.	Occ. D.	First contact	,,	,,	6 7 1	6 8	,,
19	II.		Last seen	,,	,,	6 11 11		,,
19	III.	Ecl. R.	First seen	,,	,,	7 53 3	7 55 18	,,
19	I.	Tr. Ing.	First contact	,,	,,	8 57 24	8 58	,,
19	I.		Bisection	,,	,,	9 0 33		,,
19	I.		Last contact	,,	,,	9 3 33		,,
19	II.	Ecl. R.	First seen	,,	,,	11 2 3	11 3 8	,,
19	I.	Tr. Egr.	First contact	,,	,,	11 9 52	11 15	,,
19	I.		Bisection	,,	,,	11 13 21		,,
19	I.		Last contact	,,	,,	11 16 31		,,
19	IV.	Ecl. D.	Last seen	,,	,,	13 47 36	13 24 6	,,
Mar. 14	II. (*b*)	Tr. Ing.	First contact	,,	,,	8 22 27	8 21	H. F.
14	II.		Bisection	,,	,,	8 24 41		,,
14	II.		Last seen	,,	,,	8 25 45		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N A. h m s	Observer.
Mar. 14	II. (*c*)	Tr. Egr.	Last contact	Altaz.	100	11 2 59	10 59	H. F.
Apr. 23	I.	Ecl. R.	First seen	Sheepsh. Equat.	140	8 29 1	8 28 58	A. C.
23	I.		Full brightness	,,	,,	8 30 35		,,
24	II.	Ecl. R.	First seen	,,	200	10 21 47	10 22 34	H.
24	II.		Full brightness	,,	,,	10 24 2		,,
May 8	I.	Tr. Egr.	First contact	,,	200	8 31 56	8 34	,,
8	I.		Last contact	,,	,,	8 36 11		,,
Nov. 14	I.	Ecl. D.	Last seen	,,	120	13 22 12	13 21 41	B.
14	IV.	Ecl. D.	Last seen	,,	,,	13 48 18	13 42 22	,,
18	III.	Ecl. D.	Began to fade	,,	,,	12 24 35	12 30 34	A. C.
18	III.		Last seen	,,	,,	12 31 57		,,
23	I.	Occ. R.	First seen	,,	,,	13 9 6	13 11	,,
23	I.		Bisection	,,	,,	13 11 9		,,
23	I.		Last contact	,,	,,	13 13 8		,,
23	IV.	Tr. Egr.	Last contact	,,	,,	13 38 1	13 51	,,
23	II.	Ecl. D.	Began to fade	,,	,,	13 40 26	13 42 45	,,
23	II.		Last seen	,,	,,	13 44 32		,,

Day.	Satellite.	Phenomenon		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
Nov. 30	I. (d)	Ecl. D.	Began to fade	Sheepsh. Equat.	120	11 35 20	11 36 16	A. C.
30	I.		Last seen	"	"	11 36 52		"
Dec. 7	I.	Ecl. D.	Began to fade	"	55	13 28 11	13 29 31	S.
7	I.		Last seen	"	"	13 29 46		"
31	I.	Tr. Ing.	Bisection	"	200	11 30 50	11 30	H.
31	I.		Last contact	"	"	11 33 35		"
31	III.	Ecl. D.	Last seen	"	"	12 20 10	12 18 55	"

Notes.

(*a*) Too near Jupiter for accurate observation. (*b*) Very cloudy. (*c*) Very cloudy.
(*d*) Not a very good observation; sky bright, slight haze.

The aperture of the 28-inch Equatorial is 28 inches, of the Astrographic Guiding Telescope 10 inches, of the Sheepshanks Equatorial 6·7 inches, of the Corbett Telescope 6·5 inches, and of the Altazimuth 4 inches.

The initials D., L., H., A. C., B., H. F., C. M., C. D., R. C., D. E., W. B., J., S., and W., are those of Mr. Dyson, Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Furner, Mr. Martin, Mr. Davidson, Mr. Cheeseman, Mr. Edney, Mr. Bowyer, Mr. Johns, Mr. Showell, and Mr. Witchell respectively.

On the Drift of the Surface Material of Jupiter in different Latitudes. By A. Stanley Williams.

The remarkable appearance presented by the great red spot on *Jupiter* in 1879 and subsequent years gave a great impetus to the physical observation of this planet. Notwithstanding, however, the numerous important investigations which resulted therefrom, and the many determinations of the period of rotation made from different markings in various latitudes, the question of the drift, or various rates of rotation, of the surface material in different latitudes still seems to be properly understood by only a very few. This is doubtless due in great measure to the fact that the chief investigations on the subject are scattered through the various publications of the years immediately following the apparition of the red spot, many of them not being very accessible, and that little has yet been done to bring together and adequately discuss the abundant existing material.

A great many determinations of rotation period in various latitudes were discussed by M. Belopolsky in a valuable paper published a few years ago,* the existence of the great equatorial current receiving full recognition. But, owing principally to the circumstance that a large number of results based on insufficient material were included in this discussion, the various minor, but yet very important, currents escaped notice.

In the present paper most of the chief thoroughly satisfactory determinations of rotation period are brought together and discussed under the heads of the different atmospheric currents to which they refer. The original sources of information have been referred to in nearly every case, and although it is probable that some first-class determinations may have been omitted, yet it is believed that all those contained in this paper are thoroughly to be relied upon. A good many results have been rejected from various causes; such as uncertainty as to the correct identification of the markings observed, or the short period of time over which the observations extend. And all determinations based solely upon positions derived from sketches have been rigidly excluded, experience having shown that such results are quite unreliable, except, possibly, in a few cases where the observations extend over very long periods of time.

In the present state of our knowledge there are nine distinct atmospheric currents recognisable upon *Jupiter*. Others will doubtless be added as our acquaintance with the planet becomes more intimate. But these nine currents are absolutely certain, and their boundaries are also well established within narrow limits, although it seems probable that, in some cases at least, these boundaries may vary slightly in position from time to time.

* "Ueber die Rotation des Jupiter," Mélanges mathématiques et astron. tirés du *Bulletin de l'Acad. impériale des Sciences de St.-Pétersbourg*, t. vii. 104.

With one exception the different atmospheric currents completely encircle the planet. They have therefore been arranged in zones, and numbered in order from north to south. After the number of the zone, or current, will be found the zenographical latitudes* of the north and south borders of the current. These limits are based chiefly upon my own observations and measures from 1879 to the present time, assisted by measured positions from photographs of *Jupiter* taken at the Lick Observatory. After the limits of latitude of each zone is the adopted average value of the period of rotation, R. This is not always the simple mean of the different results, and is to some extent a personal estimate of the average value. Lastly comes a complete list of the determinations of rotation period, with a short discussion of the results.

In these lists of determinations will be found :—(1) The year or years in which the observations on which the determination is based were made. (2) The period of rotation. (3) Some figures whereby some idea may be formed as to the degree of accuracy of the different results. A number followed by the letter *r* indicates the number of rotations of the planet elapsed between the first and last observations on which the period depends. A number followed by the letter *d* signifies the number of days covered by the observations. A number followed by the letter *s* gives the number of spots, where more than one was observed, the value of R in the second column being then the mean of the periods of these spots. It should be stated here that a rotation period based in this way upon several spots is much more to be relied upon for our purpose than is one derived from a single spot, however well observed. For in every zone of *Jupiter* the individual spots are found to have slightly different periods of rotation, showing that they have slight proper motions of their own. (4) The authority for the determination.

Zone I.—Lat. $+85°$ *to* $+28°$. *R* $=9^h\ 55^m\ 37^s.5$.

	h m s s			
1862	R = 9 55 25·7	128r	Schmidt	*a*
1880	32·5 ± 0·77	94r	O. Lohse	*b*
1880	35·7	2s	Hough	*c*
1881	42·4 ± 3·33	159r	O. Lohse	*d*
1888	40·8	9s	Williams	*e*
1892	38·9 ± 1·20	3s	„	*f*
1894–5	39·0	2s	Denning	*g*

Notes.—(*a*) Isolated dark spot in $+30°$. (*b*) Small dark spot in about $+34°$. (*c*) Two black spots on belt 2. (*d*) Bright spot in north polar cap. (*e*) Dark streaks extending from $+15°$ to $+70°$. (*f*) Dark streaks extending from $+40°$ to $+85°$. (*g*) Two black spots in about $+35°$.

* These have been derived by means of the table by Dr. O. Lohse, published in *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, No. 9, p. 7.

There is some evidence of a slight increase in the rate of rotation since 1862.

Zone II.—Lat. $+28°$ *to* $+24°$. $R=9^h\ 54\frac{1}{2}^m$ *to* $9^h\ 56\frac{1}{2}^m$.

The region about the second dark belt north of the equator (the north temperate belt=belt No. 3 of Professor Hough and belt No. 4 of Dr. Terby) is certainly one of the most remarkable regions of the whole planet. Here in close juxtaposition have been found both the quickest and the slowest of the great Jovian atmospheric currents. Zone II. occupies the northern half of the above-mentioned belt, and includes also the greater part of the light region intervening between it and the next dark belt to the north. Usually the drift of the surface material in Zone II. appears to differ little from that indicated by the red spot. For instance, in 1888 a number of dark streaks were visible having a north and south direction, and extending from N. lat. 60°–70° uninterruptedly across the zone. The mean value of R from nine of these streaks was $9^h\ 55^m\ 40^s\!\cdot\!8$, as given under Zone I. Some dark spots on the north temperate belt itself also rotated at a similar rate. But in the apparition of 1891–92 the region of this belt was in an abnormally disturbed state. A large protuberant mass on the north side of the belt was then observed to rotate for a time in a period of $9^h\ 54^m\ 31^s$.* In the succeeding opposition of *Jupiter* a great many spots, both light and dark, were visible on the north side of the belt. These had rotation periods considerably longer than that of the red spot. The exact average rate of rotation at this time is uncertain at present, as there were considerable variations in the case of different spots, and the observations, which are numerous, have only as yet been partially reduced. It cannot, however, well be shorter than the value, $9^h\ 56\frac{1}{2}^m$, stated above. Shortly, then, the facts in connection with this zone are as follows:—Usually the drift of the surface material is almost exactly at the same rate as the red spot. But at times, when the region is in a disturbed state, the rotation period may be as short as $9^h\ 54\frac{1}{2}^m$, or as long as $9^h\ 56\frac{1}{2}^m$. Both rates are given in the little table at the end of this paper; the latter in order to emphasise the enormous contrast at times existing between the velocity of the surface drift in this zone and in the adjacent Zone III.

Zone III.—Lat. $+24°$ *to* $+20°$. $R=9^h\ 48^m$ *to* $9^h\ 49\frac{1}{2}^m$.

In 1880 and again in 1891 an eruption of dark spots broke out on the south edge of the north temperate belt. These spots had a rapid movement from east to west compared with all other objects. The exact rate of rotation in 1880 is uncertain, but appears to have been about $9^h\ 48^m$. The observations, which

* Some particulars about this spot will be found in the *Observatory*, 1892, p. 112.

are numerous, are scattered through the publications of the time, and have never yet been properly discussed. Doubtless, as in 1891, the individual spots differed considerably amongst themselves as regards their rate of motion.

Some account of the disturbance of 1891 will be found in the *Observatory*, 1892, pp. 109–112, and also in a letter by Mr. Denning on p. 147 of the same periodical. Shortly it may be stated that the average rotation period was about $9^h\ 49\frac{1}{2}^m$, but that there were considerable differences in the rate of motion of the individual spots, and that in more than one instance sudden changes of considerable amount occurred in the velocities of some of these spots. It is a matter of great importance to determine whether this enormously swift current of Zone III. is a permanent current, or only a temporary one arising when the region is in a state of unusual disturbance. In the succeeding opposition of 1892, although the disturbance had in great measure subsided, yet a number of minute black spots were still visible on the south edge of the belt, and these moved with much the same velocity as the spots of the previous year had done. This would imply considerable permanence at least in this atmospheric current.

The great contrast between the velocity of the surface drift in the two adjacent Zones II. and III. has already been alluded to when treating of the former zone. Taking the extreme values, the difference of velocity amounts to close on 400 miles (644 kilometres) per hour. Why this enormous difference should exist between the velocities of two comparatively narrow atmospheric currents lying side by side in almost the same north latitude is a mystery at present, like so many others of the phenomena of *Jupiter*. Of the certainty of the fact, however, there is no doubt, and it must be taken into account in every theory of the planetary constitution.

Zone IV.—Lat. $+ 20°$ *to* $+ 10°$. *R.* $= 9^h\ 55^m\ 33^s{\cdot}9$.

	h m s s		
1787	R = 9 55 33·6	242r	Schroeter
1835	21·3	225r	Airy (from obs. by Glaisher)
1835	26·5 ± 0·17	2s	Beer and Mädler
1866	18·3	138r	Schmidt
1881	35·2 ± 0·85	166r	O. Lohse
1887	34·5	2s	Terby
1887	36·5	17s	Williams
1888	40·9	18s	„
1890	34·5	5s	Hough
1890–1	38·3	831r	Denning
1891	27·4	119d	Hough
1894–5	35·0	9s	Denning

The markings observed consist of white and dark spots on the north side of the north equatorial belt and in the bright zone separating that belt from the north temperate belt. On the whole the agreement between the different results is close and satisfactory. It is certain, too, that some of the differences are due to real slight variations in the velocity of the drift. There seems, however, to have been no permanent sensible change in this velocity since the first determination by Schroeter in 1787.

Zone V.—Lat. + 10° *to* — 12°. $R = 9^h\ 50^m\ 20^s$.

	h m s	s		
1879	R = 9 49 59		256r	O. Lohse
1879–80	50 3·5		302d	Hough
1880	50 8·4	± 0·22	504r	O. Lohse
1880	50 0		78r	Schmidt
1880	49 53·5		...	Kortazzi
1880	50 4·5		2s	Denning
1880–1	5		...	"
1880–1	6·6		89d	Marth (from obs. by several observers)
1880–1	7		55d	Kortazzi
1880–1	5·1		2s	Hough
1881	10·7	± 1·78	127r	O. Lohse
1880–2	7·42		...	Marth (from obs. by several observers)
1880–2	9·8		...	Hough
1881–2	9·8		252d	"
1882–3	9·8		...	"
1882–3	9·6		...	Denning
1880–5	9·84		...	Marth (from obs. by several observers)
1882–4	12·25		...	Marth (from obs. by several observers)
1883–4	12·7		...	Hough
1883–4	12·1		...	Denning
1884–5	8·2		261d	Hough
1885	14·34		...	Denning
1885	15·88		...	Marth (in his ephemeris for 1886–7)
1886	22·9		112r	Williams (from obs. by Denning)
1887	22·4		21s	Williams
1888	30·0		2s	Marth (from obs. by Williams)
1888	34·3		275r	Williams
1891	26·4		991	Hough

This zone is the zone of the great equatorial current, which was discovered by Cassini in the latter part of the seventeenth century. The determinations of the value of R since the time of this astronomer have been very numerous, as will be seen from the foregoing list. One of the most remarkable circumstances revealed by this list is the continual increase in the length of the period of rotation, amounting in ten years to about half a minute of time. At present the period seems to be still longer, the average duration for the whole zone being now probably about $9^h\ 50^m\ 40^s$. A new determination during the present opposition, based on observations of as many spots as possible, is much to be desired.

All the results contained in the above list refer to spots situated on the south side of the equator. Usually the markings lying on the north side of the equator have rotated at nearly the same rate as those situated south of the equator, but in 1887 the former rotated somewhat more slowly than the latter, and the same thing seems to have occurred in 1882. This will be seen from the following determinations of rotation period from spots lying on the north side of the equator, compared with those for corresponding years in the previous list.

1882	R = 9^h 51^m 40^s	27d	Denning
1884-5	50 9·2	238d	Hough
1887	50 40·1	5s	Williams
1891	50 31·6	69d	Hough

Zone VI.—Lat. $-12°$ *to* $-18°$. $R = 9^h\ 55^m\ 40^s$.

The great equatorial current of Zone V. extends so far south as usually to include at least one half of the south equatorial belt. This belt is generally double, appearing composed of two dark bands separated by a narrow clear interval. The material of the southernmost component appears, however, usually to rotate at about the same rate as the red spot. The great bay in the south equatorial belt opposite the latter is well known. This, however, in itself, would not prove that the material of the belt rotates at the same rate as the spot. The following results show, however, that the surface material did rotate at approximately the same rate as the red spot in the under-mentioned years.

1877	R = 9^h 55^m 40^s·5	567r	Trouvelot
1877-9	36·7	2076r	,,
1884-5	43·5	2s	Hough

Zone VII.—Lat. $-14°$ *to* $-28°$. $R = 9^h\ 55^m\ 40^s$.

This zone comprises the great red spot, and is really only part of a zone, since it is confined to a comparatively small region

of little more than 36° of longitude in extent. All the rest of the surface south of the south equatorial belt, and in the same latitude as the red spot, is comprised in the succeeding Zone VIII. The determinations of the rotation period of the red spot are very numerous and well known, and it is unnecessary to give them here.

Zone VIII.—Lat. $-18°$ *to* $-37°$. $R = 9^h\ 55^m\ 18^s{\cdot}1$.

	h m s s		
1787	R=9 55 17·6	250r	Schroeter
1862	17·2	128r	Schmidt
1872–3	19·6 ± 2·34	...	O. Lohse
1880	16·18	...	Barnard
1880–1	17·9	...	Denning
1880–1	19·07	...	Barnard
1887	18	55d	Terby
1887	17·1	3s	Williams
1889	16·7 ± 0·33	263r	„
1889	19·0 ± 0·26	326r	„
1890–1	18·3	1296r	Denning
1891	18·2	53r	„
1891	20	2s	Hough

The drift of the surface material has been remarkably uniform in this zone, no material change having taken place since the first determination by Schroeter more than 100 years ago. In fact this atmospheric current is undoubtedly the most steady one of which we have any record. Most of the results contained in the above list relate to markings in about $-30°$. The first determination of 1889 relates, however, to a dark spot in the northernmost part of the zone, and having a dark streak extending southwards to about lat. $-28°$. Many unpublished observations by the writer of white spots in the bright zone south of the south equatorial belt show that the white surface material of this region has a similar motion. In the midst of this atmospheric current the great red spot emerges, as it were, like an island in a river.

Zone IX.—Lat. $-37°$ *to* $-55°$. $R. = 9^h\ 55^m\ 5^s$.

	h m s s			
1886	R=9 55 11·14	...	Young	*a*
1888	0·9 ± 0·97	2s	Williams	*b*
1890	6·7 ± 0·21	280r	„	*c*

Notes.—(*a*) Small white spot in lat. 50° south. (*b*) Lat. $-37°$ to $-55°$. (*c*) Lat. $-36°$ to $-47°$.

The existence of this comparatively swift current so far south is a rather curious anomaly. The drift of the material near the south pole still remains to be ascertained, and the anomalous nature of this current renders it important to solve this question.

Summary of Zones.

Zone	I.	Lat. +85° to +28°	R = 9h 55m 37s·5	
„	II.	+28 .. +24	9 54½ to	9h 56m½
..	III.	+24 .. +20	9 48 to	9 49½
..	IV.	+20 .. +10	9 55 33·9	
„	V.	+10 .. −12	9 50 20	
..	VI.	−12 .. −18	9 55 40	
..	VII.	−14 .. −28	9 55 40	
..	VIII.	−18 .. −37	9 55 18·1	
..	IX.	−37 .. −55	9 55 5	

Zone VII. is incomplete, being confined to the red spot.

A glance at the above table, in which the results for the different zones are summarised, will show how anomalous and unsymmetrical are most of the currents. In particular, the northern hemisphere differs altogether from the southern hemisphere. In the latter the very remarkable region about lat. + 25° is absent altogether. Possibly the presence of the great red spot may have had something to do with this. On the other hand, the northern hemisphere lacks the red spot and the two moderately swift currents of Zones VIII. and IX., the surface drift being nearly uniform from lat. + 28° almost to the pole.*

One of the most remarkable peculiarities about these atmospheric currents of *Jupiter*, is that they circulate in a due east and west direction, and show little or no sign of movement toward or from the poles. They appear also to be usually sharply bounded, one current by another, without indication of a gradual transition from one to another, though there are exceptions to this rule. Any circulation in a north and south direction would seem to take place chiefly by means of the narrow rifts and streamers seen to traverse obliquely some of the belts and clear zones of *Jupiter*. But this subject has only just begun to be investigated by students of the planet.

It has sometimes been stated that *Jupiter* has a certain amount of resemblance to the Sun, inasmuch as in both orbs the rotation is most rapid near the Equator. I have therefore added the following table in which the solar rotation period, as com-

* A difference of one minute in the period of rotation of two currents near *Jupiter's* equator signifies a real difference of 45 miles (72 kilometres) per hour in the velocities of such currents.

puted by Spoerer's formula,* is given for the latitudes corresponding to the centres of the different zones of *Jupiter*. The rotation periods for both orbs are also expressed in terms of that for their respective equatorial zones, as this will bring out better the *relative* drifts of the solar and jovian currents :—

Latitude.	*Jupiter.* Rotation period for different latitudes. In time.	In terms of the Equatorial period.	*The Sun.* Rotation period for different latitudes. In days.	In terms of the Equatorial period.
°	h m s		d	
+46	9 55 37·5	1·0089	28·625	1·1407
+26	9 54 30	1·0071	26·165	1·0427
	9 56 30	1·0104		
+22	9 48 45	0·9973	25·855	1·0303
+15	9 55 33·9	1·0089	25·445	1·0140
0	9 50 20	...	25·094	...
−15	9 55 40	1·0090	25·445	1·0140
−21	9 55 40	1·0090	25·786	1·0276
−27½	9 55 18·1	1·0084	26·295	1·0478
+46	9 55 5	1·0081	28·625	1·1407

Ephemeris for Physical Observations of the Moon, 1896.
By A. Marth.

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
1896.	°	°	°	°	°	°
Jan. 19	321·23	−0·91	−0·55	−1·80	1·88	163·0
20	333·41	0·89	1·77	3·09	3·61	150·2
21	345·58	0·87	3·15	4·25	5·29	143·5
22	357·74	0·85	4·43	5·24	6·86	139·9
23	9·90	0·83	5·51	6·02	8·15	137·7
24	22·05	0·81	6·31	6·53	9·07	136·2
25	34·20	−0·78	−6·76	−6·75	9·54	135·2
26	46·34	0·76	6·80	6·62	9·48	134·4
27	58·48	0·73	6·43	6·13	8·87	133·8
28	70·62	0·70	5·64	5·27	7·71	133·2
29	82·75	0·67	4·49	4·05	6·04	132·1
30	94·87	0·64	3·06	2·55	3·98	129·8
31	106·00	−0·61	−1·47	−0·88	1·71	120·9

* Daily angular rotation: $\xi = 8^\circ{\cdot}548 + 5^\circ{\cdot}798$ cos latitude. *Publ. des Astrophysik. Obser. zu Potsdam,* Band x. p. 145. [I am indebted to Mr. E. W. Maunder for the above Table.]

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Combined Amount.	Direction.
1896.	°	°	°	°	°	°
Feb. 1	118·13	−0·58	+0·18	+0·90	0·92	348·7
2	131·27	0·55	1·77	2·60	3·15	325·8
3	143·41	0·52	3·20	4·10	5·20	322·1
4	155·56	0·49	4·40	5·32	6·90	320·5
5	167·72	0·46	5·32	6·19	8·16	319·5
6	179·88	−0·44	+5·95	+6·68	8·93	318·5
16	301·76	−0·19	−1·02	−2·82	3·00	160·1
17	313·95	0·16	2·42	4·03	4·70	149·1
18	326·14	0·13	3·78	5·07	6·32	143·4
19	338·32	0·11	5·04	5·90	7·75	139·6
20	350·50	0·08	6·12	6·49	8·91	136·9
21	2·67	0·05	6·96	6·79	9·71	134·5
22	14·84	−0·03	−7·50	−6·77	10·09	132·3
23	27·00	0·00	7·66	6·41	9·97	130·1
24	39·16	+0·03	7·42	5·70	9·35	127·7
25	51·31	0·06	6·73	4·64	8·17	124·7
26	63·46	0·09	5·62	3·26	6·60	119·7
27	75·60	0·13	4·13	−1·63	4·44	111·6
28	87·74	+0·16	−2·35	+0·14	2·35	86·4
29	99·88	0·19	−0·41	1·93	1·97	12·0
Mar. 1	112·02	0·22	+1·56	3·57	3·90	336·4
2	124·17	0·25	3·39	4·96	6·01	325·7
3	136·32	0·28	4·95	5·98	7·58	320·5
4	148·48	0·31	6·17	6·60	9·02	317·1
5	160·64	+0·34	+6·98	+6·81	9·74	314·5
17	307·02	+0·63	−3·92	−5·69	6·91	145·5
18	319·23	0·65	5·09	6·32	8·11	141·3
19	331·43	0·68	6·10	6·68	9·04	137·8
20	343·63	0·70	6·92	6·74	9·65	134·4
21	355·82	0·73	7·48	6·48	9·88	131·1
22	8·00	0·75	7·75	5·89	9·72	127·4
23	20·18	+0·78	−7·66	−4·97	9·12	123·1
24	32·36	0·80	7·17	3·75	8·09	117·7
25	44·53	0·83	6·27	2·27	6·67	109·9
26	56·69	0·86	4·96	−0·60	5·00	96·9
27	68·85	0·88	3·29	+1·15	3·49	70·7
28	81·01	+0·91	−1·35	+2·85	3·15	25·3

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Combined Amount.	Direction.
1896.	°	°	°	°	°	°
Mar. 29	93·16	+0·94	+0·72	+4·35	4·41	350·6
30	105·32	0·96	2·75	5·54	6·18	333·7
31	117·48	0·98	4·58	6·33	7·81	324·2
Apr. 1	129·64	1·01	6·05	6·68	9·00	318·0
2	141·81	1·03	7·07	6·61	9·67	313·3
3	153·99	1·05	7·59	6·16	9·76	309·2
4	166·17	+1·07	+7·63	+5·39	9·33	305·4
Apr. 14	288·31	+1·22	−3·78	−6·12	7·19	148·4
15	300·54	1·24	4·79	6·51	8·08	143·8
16	312·76	1·25	5·63	6·61	8·67	139·7
17	324·98	1·27	6·20	6·39	8·90	136·0
18	337·19	1·28	6·77	5·86	8·95	131·1
19	349·40	+1·30	−7·02	−5·03	8·63	125·8
20	1·61	1·31	6·98	3·91	7·99	119·4
21	13·81	1·33	6·63	2·55	7·11	111·1
22	26·00	1·35	5·95	−1·00	6·03	99·6
23	38·19	1·36	4·90	+0·64	4·94	82·5
24	50·37	+1·38	3·50	2·28	4·18	56·9
25	62·55	1·39	−1·81	3·80	4·17	24·2
26	74·72	1·40	+0·09	5·07	5·07	359·0
27	86·89	1·42	2·02	5·99	6·32	341·4
28	99·06	1·43	3·83	6·48	7·52	329·5
29	111·24	+1·44	+5·35	+6·54	8·44	320·9
30	123·42	1·45	6·45	6·19	8·93	313·9
May 1	135·60	1·46	7·07	5·48	8·94	307·9
2	147·79	1·46	7·19	4·49	8·47	302·1
3	159·98	1·47	6·85	3·31	7·61	295·9
4	172·18	+1·47	+6·17	+1·99	6·48	287·9
14	294·48	+1·50	−5·07	−6·33	8·10	141·5
15	306·72	1·51	5·48	5·82	7·97	136·7
16	318·96	1·51	5·70	5·01	7·57	131·3
17	331·19	1·51	5·77	3·93	6·97	124·3
18	343·41	1·52	5·63	2·61	6·20	114·9
19	355·63	+1·52	−5·27	−1·12	5·39	102·0
20	7·85	1·52	4·66	+0·46	4·68	84·4
21	20·06	1·53	3·79	2·04	4·30	61·7
22	32·26	+1·53	−2·66	+3·52	4·41	37·0

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Combined Amount.	Direction.
1896.	°	°	°	°	°	°
May 23	44·45	+1·53	−1·28	+4·80	4·97	14·9
24	56·64	+1·53	+0·26	+5·77	5·78	357·4
25	68·83	1·53	1·86	6·36	6·63	343·8
26	81·01	1·52	3·39	6·53	7·35	332·7
27	93·20	1·52	4·68	6·28	7·83	323·5
28	105·38	1·51	5·65	5·64	7·97	315·1
29	117·57	+1·51	+6·20	+4·69	7·77	307·2
30	129·76	1·50	6·30	3·52	7·21	299·3
31	141·96	1·49	5·97	2·19	6·36	290·2
June 1	154·17	1·48	5·26	+0·79	5·32	278·6
2	166·38	1·48	4·23	−0·61	4·28	261·8
3	178·59	+1·47	+3·02	−1·96	3·60	237·0
13	301·00	+1·37	−4·79	−4·04	6·26	130·2
14	313·25	1·36	4·52	2·71	5·27	121·0
15	325·49	1·35	4·09	−1·21	4·26	106·5
16	337·72	1·35	3·52	+0·38	3·54	83·8
17	349·95	1·34	2·80	1·96	3·42	55·0
18	2·18	+1·33	1·94	3·44	3·95	29·4
19	14·40	1·32	−0·93	4·73	4·82	11·3
20	26·61	1·30	+0·19	5·72	5·72	358·1
21	38·81	1·29	1·38	6·37	6·52	347·8
22	51·01	1·27	2·56	6·61	7·09	338·9
23	63·21	+1·26	+3·65	+6·45	7·41	330·6
24	75·40	1·24	4·55	5·89	7·44	322·5
25	87·59	1·22	5·17	5·00	7·19	314·2
26	99·78	1·20	5·46	3·85	6·67	305·3
27	111·97	1·18	5·39	2·52	5·99	295·1
28	124·17	+1·16	+4·96	+1·09	5·08	282·4
29	136·37	1·14	4·21	−0·36	4·23	265·1
30	148·57	1·12	3·20	1·76	3·65	241·2
July 1	160·78	1·10	2·10	3·07	3·72	214·3
2	173·00	1·08	+0·79	4·23	4·30	190·4
3	185·22	+1·06	−0·64	−5·20	5·24	173·0
13	307·68	+0·87	−2·88	+0·13	2·88	87·4
14	319·92	0·85	1·93	1·78	2·63	47·3
15	332·16	+0·83	−0·91	+3·32	3·44	15·3

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Combined Amount.	Direction.
1896.	°	°	°	°	°	°
July 16	344·39	+0·81	+0·14	+4·64	4·64	358·3
17	356·62	0·79	1·19	5·72	5·84	348·2
18	8·84	0·77	2·21	6·42	6·79	341·1
19	21·05	+0·75	+3·15	+6·73	7·43	335·0
20	33·26	0·72	3·97	6·64	7·73	329·3
21	45·46	0·70	4·61	6·16	7·69	323·3
22	57·66	0·67	5·05	5·34	7·34	316·7
23	69·85	0·64	5·24	4·24	6·74	309·1
24	82·04	0·62	5·16	2·94	5·94	299·7
25	94·23	+0·59	+4·80	1·53	5·03	287·5
26	106·42	0·56	4·17	+0·03	4·17	270·4
27	118·61	0·53	3·30	−1·43	3·60	246·6
28	130·81	0·50	2·23	2·79	3·57	218·6
29	143·01	0·48	+1·01	4·02	4·14	194·1
30	155·22	0·45	−0·29	5·06	5·07	176·7
31	167·43	+0·42	1·61	−5·88	6·10	164·7
Aug. 1	179·64	0·39	2·86	6·46	7·06	156·2
2	191·86	0·37	3·97	6·75	7·83	149·7
3	204·09	0·34	4·88	6·75	8·33	144·3
4	216·32	0·31	5·51	6·44	8·47	139·6
5	228·56	0·29	5·83	5·79	8·21	134·9
6	240·80	+0·27	−5·79	−4·83	7·54	129·9
7	253·04	0·24	5·40	3·57	6·47	123·5
8*	265·29	0·22	4·66	2·07	5·10	114·0
9	277·54	+0·20	−3·63	−0·40	3·65	96·3

* During the Eclipse of Aug. 8 the selenographical longitude A and latitude B of the point in the centre of the shadow cone and the position-angle P of the Moon's axis will be

Aug. 8	16h Gr.	A = −3°·45	B = −0°·21	P = 16°·10
	18	−4·48	−0·20	16·12
	20	−5·51	−0·20	16·14

To find the selenographical longitude λ and latitude β of a point on the Moon's rim in position-angle p, it will not be worth while to take the semidiameter or the latitude B into account, so that λ and β are simply given, if

$p-\mathrm{P}$ is between 0° and 180°, by $\lambda = \mathrm{A} - 90°$ and $\beta = 90° - (p - \mathrm{P})$,

and if

$p-\mathrm{P}$ is between 180° and 360°, by $\lambda = \mathrm{A} + 90°$ and $\beta = p - \mathrm{P} - 270°$.

The position-angle of the axis of the Sun during the eclipse will be 14°·07, and the heliographical latitude of the centre of the disc + 6°·40.

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1896.		°	°	°	°	°	°
Aug.	10	289·79	+0·17	−2·38	+1·34	2·73	60·6
	11	302·04	0·15	−0·98	2·96	3·12	18·3
	12	314·28	+0·13	+0·46	+4·41	4·43	354·1
	13	326·51	0·10	1·87	5·58	5·88	341·5
	14	338·74	0·08	3·14	6·37	7·10	333·9
	15	350·96	0·05	4·23	6·77	7·98	328·1
	16	3·18	+0·03	5·08	6·75	8·44	323·2
	17	15·39	0·00	5·66	6·34	8·49	318·4
	18	27·59	−0·03	+5·97	+5·60	8·18	313·3
	19	39·78	0·06	6·01	4·56	7·54	307·3
	20	51·97	0·09	5·79	3·30	6·66	299·8
	21	64·16	0·12	5·33	1·91	5·66	289·7
	22	76·34	0·15	4·65	+0·44	4·67	275·4
	23	88·53	0·18	3·77	−1·02	3·91	254·8
	24	100·71	−0·21	+2·75	2·42	3·66	228·6
	25	112·89	0·24	1·57	3·70	4·02	203·0
	26	125·08	0·27	+0·31	4·80	4·81	183·6
	27	137·27	0·30	−1·01	5·68	5·77	169·9
	28	149·46	0·33	2·33	6·33	6·74	159·9
	29	161·66	0·36	3·57	6·70	7·59	152·1
	30	173·86	−0·38	−4·70	−6·79	8·27	145·5
	31	186·06	0·41	5·65	6·57	8·66	139·5
Sept.	1	198·27	0·43	6·34	6·04	8·75	133·8
	2	210·49	0·46	6·72	5·21	8·49	127·9
	3	222·72	0·48	6·72	4·07	7·85	121·3
	4	234·95	0·50	6·31	2·68	6·85	113·1
	5	247·18	−0·52	−5·48	−1·08	5·58	101·2
	13	345·01	−0·70	+6·60	+6·40	9·19	314·3
	14	357·21	0·73	7·12	5·71	9·12	308·9
	15	9·41	0·76	7·26	4·73	8·66	303·2
	16	21·60	0·78	7·04	3·53	7·87	296·7
	17	33·79	0·81	6·53	2·18	6·88	288·5
	18	45·97	−0·83	+5·78	+0·75	5·83	277·4
	19	58·14	0·86	4·82	−0·70	4·87	261·7
	20	70·31	0·89	3·73	2·09	4·27	240·7
	21	82·48	0·91	2·53	3·37	4·21	216·9
	22	94·65	−0·94	+1·27	−4·50	4·68	195·7

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1896.	°	°	°	°	°	°
Sept. 23	106·82	−0·96	−0·03	−5·42	5·42	179·7
24	118·99	0·99	1·34	6·11	6·25	167·7
25	131·16	1·01	2·62	6·53	7·04	158·2
26	143·33	1·03	3·85	6·68	7·70	150·2
27	155·51	1·05	4·98	6·53	8·21	142·8
28	167·69	−1·07	−5·96	−6·09	8·51	135·8
29	179·88	1·09	6·72	5·35	8·59	128·7
30	192·08	1·10	7·19	4·34	8·40	121·2
Oct. 1	204·28	1·12	7·32	3·08	7·94	112·9
2	216·48	1·14	7·04	−1·61	7·22	102·9
3	228·69	−1·15	−6·31	0·00	6·31	90·0
13	350·82	−1·30	+8·01	+3·64	8·80	294·6
14	3·00	1·32	7·72	2·31	8·06	286·7
15	15·18	1·33	7·07	+0·90	7·13	277·3
16	27·35	1·35	6·15	−0·52	6·17	265·2
17	39·52	1·37	5·03	1·90	5·38	249·3
18	51·68	1·38	3·80	3·17	4·95	230·1
19	63·83	−1·40	2·50	4·29	4·97	210·2
20	75·99	1·41	+1·18	−5·22	5·35	192·7
21	88·14	1·42	−0·12	5·92	5·93	178·8
22	100·29	1·43	1·39	6·37	6·52	167·7
23	112·44	1·44	2·60	6·54	7·04	158·4
24	124·59	1·45	3·74	6·43	7·44	149·9
25	136·75	−1·46	−4·79	−6·02	7·69	141·6
26	148·91	1·47	5·71	5·33	7·80	133·2
27	161·07	1·47	6·45	4·38	7·79	124·3
28	173·24	1·48	6·97	3·20	7·67	114·7
29	185·41	1·48	7·20	1·83	7·43	104·3
30	197·59	1·49	7·08	−0·32	7·09	92·6
31	209·78	−1·49	−6·54	+1·25	6·66	79·2
Nov. 10	331·77	−1·52	+7·91	+2·44	8·28	287·2
11	343·95	1·52	7·67	+1·01	7·74	277·5
12	356·12	1·52	7·04	−0·43	7·05	266·5
13	8·29	1·53	6·09	1·81	6·35	253·4
14	20·45	1·53	4·94	3·09	5·83	237·9
15	32·61	−1·53	+3·66	−4·22	5·58	220·9

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1896.	°	°	°	°	°	°
Nov. 16	44·76	−1·53	+2·32	−5·15	5·65	204·2
17	56·90	1·53	+1·00	5·86	5·94	189·6
18	69·04	1·52	−0·27	6·32	6·33	177·6
19	81·18	1·52	1·46	6·51	6·67	167·4
20	93·31	−1·52	−2·55	−6·41	6·90	158·4
21	105·45	1·51	3·53	6·01	6·97	149·7
22	117·59	1·50	4·40	5·33	6·91	140·6
23	129·73	1·50	5·13	4·39	6·75	130·7
24	141·87	1·49	5·71	3·23	6·56	119·6
25	154·02	−1·48	−6·11	1·88	6·39	107·1
26	166·17	1·47	6·29	−0·41	6·30	93·7
27	178·33	1·45	6·20	+1·12	6·30	79·7
28	190·49	1·44	5·78	2·62	6·34	65·6
29	202·66	1·43	4·99	4·00	6·39	51·2
30	214·84	−1·42	−3·84	+5·17	6·44	36·5
Dec. 10	336·71	−1·31	+6·29	−1·67	6·51	255·1
11	348·88	1·30	5·42	3·01	6·20	240·9
12	1·04	1·29	4·31	4·18	6·00	225·8
13	13·20	1·28	3·06	5·15	5·99	210·6
14	25·35	1·26	1·75	5·90	6·15	196·5
15	37·49	1·25	+0·44	6·39	6·40	183·9
16	49·63	−1·23	−0·78	−6·61	6·66	173·3
17	61·76	1·21	1·89	6·54	6·79	163·9
18	73·89	1·19	2·85	6·17	6·79	155·3
19	86·02	1·17	3·64	5·51	6·60	146·7
20	98·15	1·15	4·26	4·57	6·24	137·1
21	110·28	1·13	4·71	3·40	5·81	125·9
22	122·41	−1·11	−4·98	−2·03	5·38	112·2
23	134·54	1·08	5·08	−0·53	5·11	96·0
24	146·68	1·06	4·99	+1·03	5·09	78·3
25	158·82	1·04	4·69	2·55	5·34	61·4
26	170·97	1·01	4·18	3·95	5·75	46·5
27	183·12	0·99	3·43	5·13	6·17	33·7
28	195·28	−0·96	−2·45	+6·03	6·51	22·0

In resuming the preparation of ephemerides for physical observations of the Moon, the last of which for 1891 were

published in vol. 51, I have adopted 1°.523 as the inclination of the plane of the Moon's equator to the ecliptic instead of the former 1°·536, and I have also taken into account the chief term of the physical libration in longitude, which depends on the Sun's mean anomaly, and the coefficient of which Professor Franz has deduced from Schlüter's heliometrical measurements.

In vol. 51 pp. 164–176 may be found a list of published lunar sketches and photographs arranged according to the Sun's position. By means of the data in the first column, consisting of a constant and a factor to be multiplied into the Sun's selenographical latitude, the colongitude (= 90° – long.) is found which the Sun must reach in order to be at the same altitude above the horizon of the spot represented as at the assigned time of the sketch or photograph, so that, by reference to an ephemeris like the present one, it is easy to ascertain the corresponding times in any lunation to about a minute. I am desirous to make a general list of photographs and sketches which have either been published or are at least accessible in the library of the Royal Astronomical Society, and I want to arrange them so that observers may easily ascertain beforehand, whenever they prepare for observing, what recurring phenomena they may look for and also what regions require to be observed. But such a general list can only be prepared for those photographs and sketches which have been properly timed, and it is a very curious and regrettable fact that, while some sketchers, instead of making sure and stating the times when the chief shadows were drawn, which are the times required, merely mention the hours or half-hours between which their drawings were made, there are still published lunar photographs without the slightest indication of the times when they were taken.

Enlarged photographs, even imperfect ones, supply at once a great amount of trustworthy information about the shadow-throwing, which, if duly made use of, relieves observers even of attempts at observing in the glare of the light so injurious to the eyes, so that they may devote themselves entirely to observations of details in a confined field, and at the most suitable occasions. Take the case of the beautiful photographs published in *Knowledge*, and therefore in the possession of or accessible to many observers. How much interesting information about the whole region from Macrobius to Plinius northward to the rim is contained in that published in the number for 1894 April, and what an amount is stored up about the region from Aliacensis to Manilius, and from Tacitus to Ptolemæus in the photograph "Sunrise on Ptolemæus," published in the number for 1894 December! But at present the greater part of the valuable evidence of these photographs is locked up and not available, simply because the key to it is withheld. No inkling, even, is to be found, in the articles accompanying the photographs, of the times when they were taken, and hitherto I have tried in vain to obtain them.

If, instead of a plain statement of the time, to the hour and

minute, and what time is meant, the age of the Moon or the time elapsed since New Moon is given to the hour, what purpose is that intended to serve? Is there any need to point out that the age of the Moon affords only a rough indication of the state of illumination, which one wants to know? That depends on the Sun's position referred to selenographical coordinates. According to the present ephemeris the Sun's centre will be in selenographical longitude $+90°$ and $-90°$, or in colong. 0° and 180° at the following times, to which are added the corresponding ages of the Moon in hours and to the minute :—

1896.	☉'s col. 0°. h m	Moon's age. h m		☉'s col. 180°. h m	Moon's age. h m
Jan. 22	4 28	186 9	Feb. 6	0 14	541 55
Feb. 20	18 44	182 31	Mar. 6	14 10	537 57
Mar. 21	8 15	177 27	Apr. 5	3 14	532 26
Apr. 19	20 50	172 27	May 4	15 23	527 0
May 19	8 35	168 49	June 3	2 46	523 0
June 17	19 43	167 0	July 2	13 45	521 2
July 17	6 38	167 3	Aug. 1	0 42	521 7
Aug. 15	17 45	168 43	30	12 5	523 3
Sept. 14	5 29	171 46	Sept. 29	0 14	527 31
Oct. 13	18 5	175 47	Oct. 28	13 20	531 2
Nov. 12	7 39	180 12	Nov. 27	3 18	535 51
Dec. 11	21 57	184 6	Dec. 26	17 50	539 59

In *Knowledge* for 1895 June representations of Maurolycus and Albategnius are published from a photograph taken at Paris 1894 March 14, $6^h\ 33^m\ 57^s$, Paris mean time, so that it is feasible to compute the data for the list, the Sun's zenith distance at the assigned time being found to have been 78°·09 at Maurolycus A and 87°·70 at Albategnius *A*.

For computing the data for the photographs of Copernicus, published in the *Harvard Annals*, vol. xxxii. p. 1, Plate V., and in vol. iii. of the *Publications of the Lick Observatory*, the positions of the Sun derived from my old ephemerides require merely the small corrections due to the physical libration and to the alteration of the inclinations, and give the zenith distances of the Sun at the central mountain of Copernicus 1889 September 4, $18^h\ 6^m$, Greenwich mean time, 77°·25; 1891 July 28, $15^h\ 49^m\ 16^s$, Pac. stand. time, 80°·39; and 1891 October 12, $7^h\ 50^m\ 54^s·5$, Pac. stand. time, 75°·98. Hence we get for due insertion in the list and for finding the times of recurrences :

Sun's Colong.		Sun's Col. Lat.	Spot.		
2°·45 + 0·202 × ☉'s lat.		2°·36 − 0°·46	Albategnius	1894 Mar. 14	Paris
2·81 + 0·986	,,	2·36 − 0·46	Maurolycus	1894 Mar. 14	Paris
32·86 − 0·169	,,	32·63 + 1·37	Copernicus	1889 Sept. 4	Harvard
34·14 − 0·170	,,	33·98 + 0·97	Copernicus	1891 Oct. 12	Lick
190·19 + 0·167	,,	190·42 + 1·37	Copernicus	1891 July 28	Lick

I am willing to extend these computations to all published or to-be-published photographs, and to the most interesting spots upon them, and also to all duly timed published sketches. But for the purpose I require to be supplied with lists of the times when the photographs were taken, and when the chief shadows on the sketches were drawn, as also due references to the publications where they are to be found, so that, in case I get the opportunity, I may refer to them and consult them in the library of the Royal Astronomical Society.

I will conclude with giving for a few sketches the predictions of the times when the Sun will reach, at the spots represented, the same zenith distance as at the assigned times, and I select for the purpose the sketches published in the *Memoirs of the British Astronomical Association*, vol. iii. part v. or Plates IV. to VII., and therefore easily accessible. The data for these sketches are:

Sun's Colong.		Sun's Colong.	Sun's Lat.	Spot.			
°		°	°			h m	
332·50 + 0·560 × ⊙'s lat.		331·86	−1·14	Piccolomini	1892 Jan. 4	5 15	Elger
337·15 + 0·201	,,	337·17	+0·07	Theophilus	1893 Apr. 21	8 42·5	Gordon
338·28 + 0·201	,,	338·48	+1·00	,,	1894 May 20	8 15	Mee
7·75 + 0·390	,,	8·09	+0·88	Thebit & Wall	1893 May 23 (not 24)	9^h 10^m	[Corder
126·87 − 0·035	,,	126·82	−1·27	Messier	1894 Nov. 15	11 30	Mee
138·51 − 0·567	,,	139·01	−0·85	Piccolomini	1891 Dec. 19	11 0	Elger

Times of Recurrences.

	Piccolomini. 332°·50 +0·560 lat. h m	Theophilus. 337°·15 +·201 lat. h m	Thebit. 7°·75 +·390 lat. h m		Messier. 126°·87 −·035 lat. h m		Piccolomini 138°·51 −0·567 lat. h m
Feb.	18 12 29	18 21 39	21 9 59	Mar.	2 5 19	Mar.	3 4 3
Mar.	19 2 51	19 11 31	22 0 5		31 18 27	Apr.	1 16 13
Apr.	17 16 11	18 0 26	20 13 5		30 6 42	May	1 4 8
May	17 4 15	17 12 18	20 0 59		29 18 13		30 15 35
June	15 15 15	15 23 25	18 11 58		28 2 28	June	29 2 58
July	15 1 35	15 10 6	17 22 27		28 16 13	July	28 14 38
Aug.	13 11 51	13 20 55	16 9 0		26 3 33	Aug.	27 2 49
Sept.	11 22 40	12 8 16	14 20 9		23 15 37	Sept.	25 15 39
Oct.	...	...	14 8 20		24 4 35	Oct.	25 5 9
Nov.	9 23 46	10 10 1	12 21 45		22 18 27	Nov.	23 19 4
Dec.	9 14 15	10 0 21	12 12 15		22 8 54	Dec.	23 9 6

It will be worth while watching on February 18 for the time of the first sunlight on the central mountain of Piccolomini, but especially on February 21, watching and timing the phenomena of sunrise over Purbach, Thebit, and the long Wall. But the suggestion must be sufficient.

Col. Cooper's Observatory,
Markree, Collooney, Ireland.

Errata in Mr. Barnard's Paper.

Vol. lvi. page 58, 3rd line from bottom, *for* Bruno *read* Bruhns.
„ 59, 5th, 10th, and 15th lines from top, *for* Bruno *read* Bruhns.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. JANUARY 10, 1896—(*continued*). NO. 4

Micrometrical Measures of the Ball and Ring System of the Planet Saturn, and Measures of the Diameter of his Satellite Titan, made with the 36-inch Refractor of the Lick Observatory in the year 1895. *With some Remarks on Large and Small Telescopes.* By E. E. Barnard, M.A.

In *Monthly Notices* for 1895 May I have given a series of measures of the ball and ring system of the planet *Saturn*, made with the 36-inch refractor of the Lick Observatory during the opposition of 1894.

In the following opposition of 1895 these measures were repeated with the same instrument, so that the final result should rest upon two years' observations. These last measures, reduced to the mean distance of *Saturn* from the Sun, are here given. It will be seen that in the main they are accordant with the results of 1894.

In the opposition of 1894 no direct measures were made of the inner diameter of the crape ring; its diameter, however, was deduced from the measures of the other elements. During the past opposition of 1895 this ring was measured directly, and the present value for its diameter is to be adopted.

In all the measures the utmost care was taken to determine the apparent elements without prejudice from the previous work. As I have previously stated, the objects measured were carefully bisected with the middle of the wire in each case. As the wires are only about $0''\cdot1$ in thickness, this could be done with considerable precision.

So far as the surface markings were concerned, no new objects were seen. Much discussion has arisen over the apparently

abnormal lack of details shown in my previous observations of *Saturn* with the 36-inch. From this fact, and other considerations, the general impression seems to be that, from various causes, great telescopes are inferior to smaller ones for showing the delicate markings on the surface of a planet. I think this is a false impression, and does an injustice to great telescopes in general.

I shall not try to explain why the numerous details reported to have been seen on some of the planets with very small telescopes have not been verified with the great telescope on Mount Hamilton. Let it be sufficient, however, for me to say that my faith in the ability of this great instrument to show anything that can be seen in a smaller telescope has never been shaken.

At the opposition of *Saturn* in 1895, as on all previous occasions, no spots were seen upon the planet with any aperture, either in early twilight, at dawn, or after dark.

It is well to state here that all the measures and observations that I have made with the great telescope have been with the full aperture, except on the two following occasions.

To test the effect of reduction of aperture on the visibility of markings on *Saturn*, the following experiments were made:—

On 1895 July 14 the aperture was reduced by a diaphragm to 12 inches. *Venus* was first tried with this, but no definite markings were seen. The image was, of course, duller and steadier. I have on many occasions seen markings on this planet, but they have always been so extremely vague and ill-defined that nothing definite could be made of them.

These were noticed on this last occasion with the full aperture and also with the aperture reduced, but they were not seen any better with the smaller aperture, though one might expect, under some conditions, an improvement in the case of *Venus* by reducing the aperture. On this evening *Saturn* was also examined with both the full and reduced apertures. With the 12 inches the image was steadier, but no indication of additional markings could be made out. With the diaphragm removed the image was much brighter and everything was better seen.

The same experiment was tried on July 15, and the following notes were made:—

"1895 July 15.—At 7^{h} 45^{m} observed *Saturn* with the 36-inch. Seeing = 4 (5 perfect). High west wind, but not striking the telescope. After carefully examining the planet [with full aperture] put a 12-inch diaphragm over the O.G. The image was then of a dull yellow, but the details were not so distinct as with the full aperture. No abnormal features could be seen. The view was more satisfactory without the diaphragm. Magnifying powers of 350 and 520 were used. With the full aperture the narrow dusky belt at the equator was distinct, as was also the small dark north polar cap. These were not so distinct with the 12-inch aperture, though they were seen fairly well with it."

These experiments were carefully made to satisfy the desire that seems to exist in the minds of a number of astronomers to know if a reduction of the aperture of this great telescope would make it show planetary markings that were not visible with the full aperture. From these experiments, and from others that I have made in this direction with smaller telescopes, I am convinced that everything that can be seen with this telescope diaphragmed down can be seen with the full aperture, and furthermore, such can be better seen with the full aperture when the air is steady. If the object is very bright, or the air unsteady, I think a reduction of aperture would be an improvement. But, as I have said previously (*Monthly Notices* for 1895 May), it is better to reduce the light by a cap, with a small hole in it, placed over the eyepiece.

In concluding the subject of reduced apertures, I would give it as my opinion that, whatever value small apertures may seem to have for seeing faint planetary markings in the hands of other observers, for my own part a large telescope, if the air is steady, is much better for planetary and other visual work. For diffused and large nebulæ—for contrast—a small telescope is always better than a large one.

It has always appeared to me, when I have heard large telescopes decried in this connection, that if these same observers could look at *Saturn* or *Jupiter* with a great telescope, under first-class conditions, they would themselves be astonished at the difference, and would at once decide for the larger aperture. Until one has used a large telescope under good conditions he can form no sort of idea as to the real appearance of one of the celestial bodies in such a telescope as that on Mount Hamilton. I have used both small and large telescopes, and can appreciate the full value of my statement. If the seeing, however, is bad or very indifferent, I would prefer the smaller telescope.

My drawing of *Saturn* in *Monthly Notices* for 1895 May has not been correctly reproduced. The crape ring has been made entirely too light; the original drawing showed but little contrast between this ring and the sky. My statements about the crape ring in that paper refer only to the original drawing, and in no way to the reproduction.

There is one question that may naturally arise in speaking about the visibility or invisibility of planetary markings in a great telescope. In failing to verify certain things shown on drawings with small glasses, does a large telescope show anything not shown on these drawings? If not, it would rather speak in favour of the smaller instrument for such work. A few remarks on this subject may not be out of place in this paper. I shall speak from a personal experience.

So far as *Jupiter* is concerned, I have paid great attention to this planet for the past fifteen years, and have carefully observed and drawn it with all sized telescopes, from the smallest to the largest. I must say that with all the smaller telescopes the

details on *Jupiter* have been very much inferior to those seen with the 36-inch. Even with the fine 12-inch of the Lick Observatory the view of this planet's surface is very much inferior to that given by the great telescope. I mean by this that there are finer details seen in the 36-inch, and that all the details seen in the 12-inch are clearer and better seen in the large telescope. The view of this splendid planet, with this noble instrument, under first-class conditions, is magnificent, and the amount and intricacy of detail is utterly beyond the ability of an observer to depict. But since these are always changing, and comparisons of observations of this planet at different times are not strictly possible, let us take another object—*Mars*—where there seems to be at least an appearance of stability. I have carefully observed, drawn, and measured the surface markings of this planet with the 36-inch during the past two oppositions. I have also examined a great many drawings made of it with all kinds of telescopes, and must confess that I have been amazed at some of the details shown on many of these drawings. I must confess also that in many respects it seems proved, if we are to take the testimony of the drawings themselves, that the smaller the telescope the more peculiar and abundant are the Martian details.

In the past opposition of 1894, *Mars*, when on the meridian, had a high altitude, and was extremely favourably placed for observing with the 36-inch.

On several occasions during that summer, principally when the planet was on the meridian shortly after sunrise—at which time the conditions for good seeing are often exceptionally fine at Mount Hamilton—its surface with the great telescope has shown a wonderful clearness and amount of detail. This detail, however, was so intricate, small, and abundant, that it baffled all attempts to properly delineate it. Though much detail was shown on the bright "continental" regions, the greater amount was visible on the so-called "seas." Under the best conditions these dark regions, which are always shown with smaller telescopes as of nearly uniform shade, broke up into a vast amount of very fine details. I hardly know how to describe the appearance of these "seas" under these conditions. To those, however, who have looked down upon a mountainous country from a considerable elevation, perhaps some conception of the appearance presented by these dark regions may be had. From what I know of the appearance of the country about Mount Hamilton as seen from the observatory, I can imagine that, as viewed from a very great elevation, this region, broken by canyon and slope and ridge, would look just like the surface of these Martian "seas." During these observations the impression seemed to force itself upon me that I was actually looking down from a great altitude upon just such a surface as that in which our observatory was placed. At these times there was no suggestion that the view was one of far-away seas and oceans, but exactly the reverse. Especially was I struck with this appearance in the great

"ocean" region of the Hour-glass Sea, and especially in the equatorial portion of this region. These views were extremely suggestive and impressive. I have not seen these small and delicate details described elsewhere, and I feel confident they would scarcely be shown in a much smaller telescope. The details shown on the "continental" regions were usually irregular features, principally delicate differences of shade. No straight hard sharp lines were seen on these surfaces, such as have been shown in the average drawings of recent years. I would mention specially the region of the Solis Lacus and following it. Some short diffused hazy lines—rather irregular—were also seen here, running between several of the small very black spots that abound in this region. On several dates—principally about September 30—two long hazy parallel streamers were seen running from the preceding end of the "Cimmerian Sea" towards the north following.

These, however, are details that will be treated of specially when my work upon *Mars* is published. They are presented here simply to show that the views with the great telescope have in nowise been deficient in important details.

Equatorial Diameter of Saturn.

1895.	Measured. ″	Reduced to MΔ. ″
Mar. 4	18·43	17·58
10	18·37	17·96
Apr. 7	19·17	17·75
14	19·41	17·92
May 6	19·12	17·68
12	19 23	17·84
June 17	18·73	18·08
July 1	18·25	17·99
8	18·08	18·03
	Mean	17·875

These are corrected for phase by Marth's ephemeris.

Polar Diameter of Saturn.

1895.	Measured. ″	Reduced to MΔ. ″
Mar. 4	17·12	16·43
10	17·01	16·18
Apr. 14	17·69	16·33
May 6	17·56	16·23
12	17·56	16·29
July 1	16·63	16·39
8	16·43	16·39
	Mean	16·320

Correcting this value for the inclination of the axis towards us we have

Corrected Polar Diameter = 16″·143.

Outer Diameter of Outer Ring.

1895.	Measured. ″	Reduced to MΔ. ″
Mar. 4	41·97	40·28
10	42·12	40·06
24	43·25	40·48
Apr. 7	43·26	40·06
8	43·09	39·92
14	43·36	40·03
15	43·62	40·27
May 6	43·22	39·96
12	43·14	40·01
June 10	42·04	40·14
17	42·05	40·59
24	40·85	39·88
July 1	40·76	40·18
7	40·12	39·95
8	40·29	40·19
	Mean	40·013

Diameter Middle of Cassini's Division.

1895.	Measured. ″	Reduced to MΔ. ″
Mar. 4	36·03	34·58
10	36·24	34·47
24	37·08	34·70
Apr. 7	37·19	34·44
8	37·27	34·53
14	37·41	34·54
21	37·48	34·56
May 6	37·39	34·55
12	37·52	34·80
17	36·29	35·03
24	35·45	34·61
July 1	35·21	34·71
7	34·67	34·52
8	34·55	34·46
	Mean	34·607

With these measures of the diameter of the Cassini division and the measured width of that division, we have for the outer diameter of inner ring

$$34''\cdot135.$$

And for the inner diameter of the outer ring

$$35''\cdot079.$$

Inner Diameter of Inner Bright Ring.

1895.	Measured.	Reduced to MΔ.
	″	″
Mar. 4	26·85	25·77
10	26·99	25·67
24	27·22	25·47
Apr. 7	27·69	25·64
8	27·49	25·47
14	27·83	25·69
21	27·77	25·60
May 6	27·94	25·83
June 17	26·75	25·82
24	26·44	25·81
July 1	26·18	25·81
7	25·58	25·47
8	25·65	25·58
	Mean	25·664

Inner Diameter of Crape Ring.

1895.	Measured.	Reduced to MΔ.
	″	″
Mar. 4	21·36	20·50
10	21·57	20·51
24	21·69	20·30
Apr. 7	22·32	20·67
8	21·97	20·36
14	22·73	20·98
21	22·23	20·50
May 12	22·38	20·76
June 17	21·19	20·46
24	20·87	20·38
July	20·68	20·39
	Mean	20·528

Width of Crape Ring.

1895.	Preceding. Measured.	Preceding. Red. MΔ.	Following. Measured.	Following. Red. MΔ.
Apr. 22	2″·70	2″·49	2″·65	2″·45

Width of Cassini's Division.

1895.	Measured.	Reduced to MΔ.
Mar. 4	0″·37	0″.35
10	0·60	0·57
Apr. 22	0·56	0·52
May 12	0·46	0·42
June 24	0·51	0·50
	Mean	0·472

Measures of the distance from the centre of the Cassini Division to nearest limb of Planet.

1895.	Preceding. Measured.	Preceding. MΔ.	Following. Measured.	Following. MΔ.
Feb. 4	8″·13	8″·16	8″·18	8″·21
5	8·19	8·20	8·12	8 13
18	8·52	8·35	8·44	8·27
Mar. 3	8·67	8·33	8·78	8·44
	Mean	8·259	Mean	8·267

The values for the "preceding" have been corrected for the phase of the ball. I have called attention to the fact (*Monthly Notices*, 1895 May, p. 381) that these measures and the others seem to show that the ball is symmetrically placed in the rings.

Collecting the measures for the year 1895, we have the following values for the dimensions of *Saturn's* ring system.

Equatorial diameter of Saturn	17″·875
Polar diameter of Saturn	16·143
Outer diameter of Outer Ring	40·013
Inner diameter of Outer Ring	35·079
Centre of Cassini Division	34·607
Outer diameter of Inner Ring	34·135
Inner diameter of Inner Ring	25·664
Inner diameter of Crape Ring	20·528
Width of Cassini Division	0·472

To represent the results of the two years' measures of the different elements, I have taken the means of the measures of the two sets, giving weight according to the number of observations.

Final Results from the Two Years' Measures. Reduced to Distance = 9·538861

Equatorial diameter of Saturn	17″·800 (21 nights' obs.)
Polar diameter of Saturn	16·241 (19 nights' obs.)
Outer diameter of Outer Ring	40·108 (23 nights' obs.)
Inner diameter of Outer Ring	35·046
Centre of Cassini Division	34·517 (21 nights' obs.)
Outer diameter of Inner Ring	33·988
Inner diameter of Inner Ring	25·647 (19 nights' obs.)
Inner diameter of Crape Ring	20·528 (11 nights' obs.)
Width of Cassini Division	0·529 (15 nights' obs.)

For comparison, these differ from Professor Hall's measures of 1884–87, by the following values, H. – B.

Differences H. – B.

Equatorial diameter of Saturn	–0″·08
Outer diameter of Outer Ring	+0·34
Inner diameter of Outer Ring	–0·10
Centre of Cassini Division	+0·01
Outer diameter of Inner Ring	+0·12
Inner diameter of Inner Ring	+0·10
Inner diameter of Crape Ring	–0·01
Width of Cassini Division	–0·11
Mean difference H. – B.	+0·034

The agreement is as close as could be desired in the work of two observers using different instruments. The large difference in the measures of the outer diameter of the ring is strikingly conspicuous considering the agreement in the other elements, but, taking into account the distance measured, this discrepancy is not very great.

It is possible, however, that this may be a real difference due to some excentricity in the outer part of the ring.

The results for the polar and equatorial diameters give a polar compression of $\frac{1}{11{\cdot}42}$.

By an error, the value of the polar compression in my previous paper (*Monthly Notices*, 1895 May, p. 377) was given as $\frac{1}{11{\cdot}44}$; it should have been $\frac{1}{12{\cdot}35}$.

During the past opposition I also repeated my measures of the diameter of *Titan*. It was seldom the disc could be clearly distinguished, but no measures were made unless the satellite was well seen.

Two sets of measures were made of it on June 3 and June 24 at different times during the measures of the planet.

Diameter of Titan.

1895.	Measured.	Reduced to MΔ.
Mar. 10	0″·68	0″·65
Apr. 14	0·76	0·70
May 12	0·73	0·68
June 3	0·78	0·74
3	0·75	0·71
24	0·56	0·55
24	0·64	0·63
	Mean	0·666

Combining the two years' measures of this satellite, the following results for the diameter of *Titan* at the mean distance of *Saturn* from the Sun :

0″·633

Following are the final results of all my measures of *Saturn*, reduced to English miles—the Sun's mean distance being 92,879,000 miles.

Equatorial diameter of Saturn	76,470 miles.
Polar diameter of Saturn	69,770 ,,
Outer diameter of Outer Ring	172,310 ,,
Inner diameter of Outer Ring	150,560 ,,
Outer diameter of Inner Ring	146,020 ,,
Inner diameter of Inner Ring	110,200 ,,
Inner diameter of Crape Ring	88,190 ,,
Width of Cassini Division	2,270 ,,
Diameter of Titan	2,720 ,,

This closes my micrometrical work on *Saturn* and his system.

Kenwood Observatory, Chicago, Ill.
1895 *December* 24.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LVI. February 14, 1896. No. 5

A. A. Common, LL.D., F.R.S., President, in the Chair.

Cyril E. Ashford, M.A., The School, Harrow ;
Frank Arthur Bellamy, F.R.Met.Soc., University Observatory, and 4 St. John's Road, Oxford ;
Thomas Folkes Claxton, Royal Alfred Observatory, Mauritius ;
Philip H. Cowell, B.A., Trinity College, Cambridge ;
Robert Fermor Rendell, B.A., The Glen, Blackheath Hill, S.E. ;
George Albert Smith, St. Ann's Gardens, Brighton ; and
Charles Albert Taylor, 33 Argyle Street, Argyle Square,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

William Anderson, Gentleman, Ballee House, Ballymena, Co. Antrim, Ireland (proposed by A. A. Rambaut) ;
Thomas Frederick Furber, Chief Computer, Trigonometrical Survey of New South Wales, Department of Lands, Sydney, N.S. Wales, Australia (proposed by R. T. A. Innes) ;
Frank L. Grant, M.A., 58 Kelvington Street, Glasgow (proposed by L. Becker) ;
Edward Ayearst Reeves, Royal Geographical Society, Savile Row, W., and 24 Clyde Road, Wallington, Surrey (proposed by John Coles) ;
George Frederick Herbert Smith, B.A., Scholar of New College, Oxford (proposed by H. H. Turner) ; and
T. M. Teed, C.E., F.R.C.S., 188 Camberwell Grove, Denmark Hill, S.E. (proposed by John Coles).

Report of the Council to the Seventy-sixth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1894	247	392	1	640	48	1	689
Since elected	+4	+28	...	...	...	...	...
Deceased	−8	− 6	−1	...	−2	...	...
Resigned	...	−11	...	...	...	...	...
Removals	+2	− 2	...	...	...	...	...
Expelled	...	−10	...	...	...	...	...
December 31, 1895	245	391	...	636	46	1	683

Mr. Knobel's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1895 January 1:—						
At Bankers', as per Pass Book	391	15	1			
Outstanding Cheque	23	2	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	13	8	7			
In hand of Assistant Secretary on Petty Cash Account	15	0	2			
				443	5	10
Dividends on £13,200 Consols, 2¾ per cent. ...	350	18	4			
„ on £900 New 2½-per-cent. Stock ...	21	15	0			
„ on £1,250 Metropolitan 3-per-cent. Stock	36	5	0			
				408	18	4
Received on account of Subscriptions:—						
Arrears	174	6	0			
Annual Contributions for 1895	585	18	0			
„ „ 1896	10	10	0			
Admission Fees	60	18	0			
First Contributions	40	19	0			
				872	11	0
Composition Fees				126	0	0
Sales of Publications:—						
At Williams & Norgate's, 1894	7	3	7			
At Society's Rooms, 1895	46	6	9			
Sale of Photographs	21	16	0			
				75	6	4
Income Tax refunded by Commissioners of Inland Revenue				13	13	7

Audited and found correct, 1896 January 8.

H. P. Hollis,
Sidney Waters,
D. Smart.

	£	s.	d.
	£1,939	15	1

Astronomical Society, from 1895 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
" " for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	7	16	6			
				10	9	0
Printing, &c., *Monthly Notices*	405	9	6			
" Miscellaneous	40	4	0			
Plates (Woodbury type)	2	8	0			
				448	1	6
Turnor and Horrox Fund: Purchases for Library	27	8	3			
Binding Books in Library	31	0	6			
Copying Photographs	4	16	6			
				63	5	3
Grant to Photographic Committee				20	0	0
Clerk's Wages	46	11	0			
Postage and Telegrams	73	5	7			
Carriage of Parcels	2	9	5			
Stationery and Office Expenses	8	6	0			
				130	12	0
Expenses of Meetings	20	0	0			
Lantern Expenses	4	14	1			
				24	14	1
House Expenses	61	10	7			
Coals and Gas	72	2	0			
Electric Light Expenses	7	0	11			
Rental of Wire for Time Signal, &c.	5	6	0			
Sundry Fittings and Repairs...	15	8	7			
Sundries	6	8	3			
				167	16	4
Decorating Society's Rooms, Trollope & Sons (on account)	250	0	0			
Carpets, &c., Maple & Co.	50	9	8			
Pedestals for Busts, &c., Macdonald & Co. ...	26	17	6			
Fittings in Upper Library, Brown & Blomfield ...	86	10	0			
Furniture in Office, &c.	7	8	0			
				421	5	2
Lee and Janson Fund Grants				4	0	0
Cheque Book and Deductions on Cheques				0	10	1
Balances, 1895 December 31:—						
At Bankers', as per Pass Book	286	12	10			
Outstanding Cheques	24	6	6			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	14	8	4			
In hand of Assistant Secretary on Petty Cash Account	3	3	0			
In hand of Assistant Secretary on account of Sales of Photographs	20	11	0			
				349	1	8
				£1,939	15	1

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1895, and have found and certified the same to be correct. The cash in hand on 1895 December 31, including the balance at the bankers', &c., amounted to £349 1*s.* 8*d.*

The funded property of the Society is the same as at the end of the previous year.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

The Auditors suggest that it is desirable that a notice be distributed with the February number of the *Monthly Notices*, pointing out that the annual subscription for the forthcoming year is then due.

With reference to the Composition Fees mentioned in the accounts, the Auditors suggest that the time has come when Section V. of the Bye-laws of the Society, which relate to payment of subscriptions, should be revised. They consider that twenty guineas paid on entrance is not now fairly proportionate to an annual subscription of two guineas, and they think a scheme should be devised by which subscribers might be allowed to compound at any later time on payment of a reduced sum—the reduction being in proportion to the amount of previous subscriptions paid.

(Signed) H. P. Hollis,
Sidney Waters,
David Smart.

1896 *January* 8.

Trust Funds.

The Turnor Fund: A sum of £450 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £100 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £323 16*s.* 6*d.* 2¾-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £300 2¾-per-cent. Consols, the interest to be given in medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1896 *January* 1.

	£	s.	d.	£	s.	d.
Balances, 1895 December 31 :—						
At Bankers', as per Pass Book	286	12	10			
Outstanding cheques	24	6	6			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	14	8	4			
In hand of Assistant Secretary on Petty Cash Account	3	3	0			
In hand of Assistant Secretary on account of Sales of Photographs	20	11	0			
				349	1	8
Due on account of Subscriptions :—						
2 Contributions of 4 years' standing... ...	16	16	0			
6 „ 3 „	37	16	0			
32 „ 2 „	134	8	0			
67 „ 1 „	140	14	0			
6 Admission Fees, &c....	18	18	0			
	348	12	0			
Less 5 Contributions paid in advance ...	10	10	0			
				338	2	0
Due from Messrs. Williams & Norgate for sales of Publications during 1895				20	13	8

£13,200 2¾-per-cent. Consols, including the Lee and Janson Fund, the Turnor and Horrox Fund, and the Jackson-Gwilt Fund.

£900 New 2½-per-cent. Consols.

£1,250 Metropolitan 3-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments ; Furniture, &c.

Unsold Publications of the Society.

1 Gold Medal.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	153	...
I. Part 2	42	...	XXXI.	136	...
II. Part 1	51	3	XXXII.	148	...
II. Part 2	17	3	XXXIII.	157	...
III. Part 1	65	1	XXXIV.	159	2
III. Part 2	83	1	XXXV.	105	3
IV. Part 1	78	3	XXXVI.	188	8
IV. Part 2	90	3	XXXVII. Part 1	334	7
V.	101	3	XXXVII. Part 2	279	8
VI.	119	6	XXXVIII.	264	1
VII.	141	3	XXXIX. Part 1	230	3
VIII.	125	3	XXXIX. Part 2	236	3
IX.	132	3	XL.	253	1
X.	144	...	XLI.	402	...
XI.	151	...	XLII.	227	3
XII.	157	...	XLIII.	228	...
XIII.	155	...	XLIV.	208	1
XIV.	363	...	XLV.	242	...
XV.	136	...	XLVI.	222	3
XVI.	161	1	XLVII. Part 1	3	...
XVII.	145	1	XLVII. Part 2	18	...
XVIII.	137	1	XLVII. Part 3	2	...
XIX.	147	...	XLVII. Part 4	10	...
XX.	136	1	XLVII. Part 5	8	...
XXI. Part 1	310	...	XLVII. Part 6	9	...
XXI. Part 2	98	...	XLVII.	196	1
XXI. 1 & 2 (together)	58	...	XLVIII. Pt. 1	245	1
XXII.	160	1	XLVIII. Pt. 2	239	1
XXIII.	144	...	XLIX. Part 1	389	5
XXIV.	151	1	XLIX. Part 2	270	1
XXV.	161	...	L.	271	...
XXVI.	167	1	LI.	400	6
XXVII.	419	1	Index to *Memoirs*	628	3
XXVIII.	378	...			
XXIX.	400	...			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	57	...	XXIX.	51	...
II.	59	...	XXX.	63	2
III.	...	...	XXXI.	92	...
IV.	...	...	XXXII.	111	5
V.	...	...	XXXIII.	94	...
VI.	43	...	XXXIV.	70	1
VII.	2	...	XXXV.	54	...
VIII.	153	2	XXXVI.	27	1
IX.	24	3	XXXVII.	34	3
X.	172	1	XXXVIII.	97	2
XI.	184	...	XXXIX.	95	...
XII.	106	2	XL.	106	3
XIII.	177	2	XLI.	106	5
XIV.	176	3	XLII.	115	1
XV.	168	2	XLIII.	112	2
XVI.	154	1	XLIV.	115	2
XVII.	167	1	XLV.	117	1
XVIII.	242	...	XLVI.	112	...
XIX.	52	...	XLVII.	130	2
XX.	31	...	XLVIII.	122	1
XXI.	16	...	XLIX.	116	9
XXII.	30	...	L.	118	11
XXIII.	17	...	LI.	119	9
XXIV.	22	...	LII.	117	12
XXV.	14	...	LIII.	119	15
XXVI.	10	1	LIV.	119	19
XXVII.	3	...	LV.	135	9
XXVIII.	70	...	Index ...	556	5
Library Catalogue				557	2

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LV., no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.

No. 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{5}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{3}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

No. 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.
" 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.
" 47. (21) Box sextant; reflecting plane and level.
" 48. (22) Prismatic compass, by Troughton and Simms.
" 49. (23) Mountain barometer.
" 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
" 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.
" 52. (26) Dipping needle, by Robinson.
" 53. (27) Compass needle, mounted for variation.
" 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
" 55. (29) Box of magnetic apparatus.
" 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
" 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
" 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon and stand.
" 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.
" 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches; tripod stand.
" 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
" 62. (36) A pantograph.
" 63. (37) A noddy.
" 64. (38) A small Galilean telescope with object-glass of rock crystal.
" 65. (39) Five levels.
" 66. (40) 18-inch celestial globe.
" 67. (41) Varley stand for telescope.
" 69. (43) Telescope, with object-glass of rock crystal.
" 71. Portable altazimuth tripod.
" 72. Four polarimeters.
" 74. Registering spectroscope, with one large prism.
" 76. Two five-prism direct-vision spectroscopes.
" 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
" 79. Spectroscope.
" 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
" 81. A back-staff, or Davis' quadrant.
" 82. A nocturnal or star dial.

No. 83. An early non-achromatic telescope, of about 3 feet focal length in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
„ 91. Astronomical time watch case, by Professor Chevalier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. } Two old sun-dials.
„ 118. }
„ 119. Specimens of diffraction gratings, by Prof. W. A Rogers.

No. 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant, by Troughton.
„ 131. Double box sextant, by Cary.

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
2 Abney lenses used in photographing the corona.
2 Dallmeyer negative enlarging lenses.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatorial, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-inch transit and stand, to Mr. B. T. Moore.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 1), to Mr. C. Thwaites.
„ 30. (4) 3¼-inch equatorial, to Mr. E. B. Powell.
„ 31. (5) 2¾-inch telescope and stand, to Mr. F. J. Wardale.
„ 47. (21) Box sextant and horizon, to Mr. C. H. Johns.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 69. (43) Telescope with rock-crystal object glass, to Dr. W. Huggins.
„ 72. (*a*) Polarimeter, to Dr. A. M. W. Downing.
„ 72. (*c*) Polarimeter, to Professor C. M. Smith.
„ 78. 9⅓-inch reflector and stand, to Mr. Maxwell Hall.
„ 85. Double image micrometer, to Mr. B. T. Moore.
„ 99. 12-inch transit with portable stand, to Mr. H. T. Vivian.
„ 119. Diffraction gratings, to Mr. B. T. Moore.
„ 120. 6-prism spectroscope, to Mr. C. Thwaites.

No. 123. 6-inch telescope, by Grubb (object-glass only) to Mr. W. E. Wilson.

„ 125. 6-inch refractor by Simms, to Dr. A. A. Common.

„ 126. 3½-inch portable refractor, by Tulley, to Mr. H. Sadler.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Mr. S. C. Chandler, for his discussion of the Variation of Latitude, his work on Variable Stars, and other astronomical investigations.

Publications of the Society.

Volume LI. of the *Memoirs* has been published during the past year, containing the following papers:—

"On the investigation of the division errors of the scales of the Cape Repsold Measuring Apparatus, and the determination of the errors of the Oxford *réseau*." By David Gill.

"Spectrum of *Nova Aurigæ*." By Rev. W. Sidgreaves.

"Physical observations of *Mars*, made at the Allegheny Observatory in 1892." By J. E. Keeler.

"Comparison of the Greenwich Ten-Year Catalogue (1880) with the Cape Catalogue (1880)." By H. H. Turner and H. P. Hollis.

"An experiment with a 12½-inch refractor, whereby the light lost through the secondary spectrum is separated out and rendered approximately measurable." By H. Dennis Taylor.

"On the R–D discordance." By H. H. Turner and W. G. Thackeray.

"On the rotation and mechanical state of the Sun." By R. A. Sampson.

"Index Catalogue of Nebulæ found in the years 1888–94, with notes and corrections to the New General Catalogue." By J. L. E. Dreyer.

"Double Star Observations, 1892–94." By W. H. Maw.

"A determination of the constant of nutation from Greenwich meridian observations of *Polaris*, 1836–93." By W. G. Thackeray.

"Further measures of double stars, made at the Temple Observatory, Rugby, during the years 1890–95." By G. M. Seabroke and H. P. Highton.

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :--

Fellows :—Isaac Brown.
James Campbell.
Arthur Cayley.
Sir James Cockle.
E. J. Collingwood.
Richard Dunkin.
Sir C. C. Graham.
J. R. Hind.
F. R. Hughes.
A. L. Kaye.
A. J. Melhuish.
E. H. Nightingale.
John Nottingham.
O. A. L. Pihl.
Alfred White.

Associates :—Gustav Spörer.
Friedrich Tietjen.

There has always been a little ambiguity connected with these lists of deceased Fellows; the names of those who have died between December 31 and the date of the Annual Meeting being generally included in this list, but omitted in the count given in the table at the beginning of this Report; and in these cases, too, it is often difficult to obtain the particulars in time for the Report. Thus the names of Professor Cayley and Sir James Cockle were included in the list of the last Report, and a notice of Sir James Cockle was given, but not of Professor Cayley.

ISAAC BROWN was born at Amwellbury, a farm near Ware, in Hertfordshire, in the year 1803. Throughout his long life he was a member of the Society of Friends. His vocation was teaching —first in his own private school at Hitchin in 1829, which was removed to Dorking in 1845, and in 1848 as Principal of the Friends' Flounder's Institute at Ackworth, in Yorkshire, a post which he retained for twenty-two years.

In 1870, on resigning this appointment, he settled for the remainder of his life at Brantholme, Kendal.

He was twice married, and had six children by his first wife, four of whom survive him.

Highly cultured, refined and scholarly in all his tastes, and with a mind ever reaching after things high and heavenly, it was little wonder that the bent of his purely scientific pursuits turned strongly towards astronomy, a science which, in all its branches, retained its charm for him and exercised his unimpaired intellectual faculties unto the end.

Isaac Brown was elected a Fellow of the Royal Astronomical Society in 1851. While at the Flounder's Institute he was in the habit of using a 4½-inch refractor by Cooke & Sons, also a transit instrument for obtaining correct astronomical time. As years went on every new discovery was to him a subject of interest and delight, and but for his advanced age, a fact not always easy to realise, he would probably have become a member of the British Astronomical Association, a society in the establishment and progress of which he took the deepest interest, hailing with especial satisfaction its admission of ladies to equal honours.

Very recent letters exist in which, in his peculiarly fine and clear handwriting, he dilated on the wonderful discoveries of modern astronomy, as much in touch with the times he lived in as any of the younger votaries of science.

Isaac Brown was for forty-five years a Fellow of the Royal Meteorological Society, and also in earlier life devoted considerable time to botanical research.

He died on 1895 November 3.

[For the above particulars the Council is indebted to Miss E. Brown.]

James Campbell was fourth child and only surviving son of Major-General Sir James Campbell, K.C.B., of Sanda, Argyllshire, and his wife the Lady Dorothea Louisa Cuffe, daughter of the Earl of Desart.

He was born 1822 October 30, at Mount Lavinia, in Ceylon, of which his father was then Governor. Sir James was also Governor of Grenada afterwards. Before this he had served with distinction throughout the Peninsular Campaign in command of the 94th Regiment. Owing to his position and occupation the family were constantly travelling, and James was educated abroad, chiefly in France. He showed his strong taste for study while very young, and took the degree of Bachelier-ès-Arts in Paris at an unusually early age. Later on, in London, he studied law, and was called to the Bar (Middle Temple), but he never practised.

When Vice-Admiral Sir C. Napier took his fleet in 1854 to the Baltic, Mr. Campbell accompanied it in his yacht the *Esmeralda*, and was present at the bombardment and capture of Bomarsund. It was during this time that his vessel was stationed

as a kind of light-ship near the "Bell Rock" to warn others from this dangerous spot. Early in the Italian War of Independence Mr. Campbell enlisted in the Foreign Legion, and served as aide-de-camp to Garibaldi, whom he knew and greatly admired. When the latter came to London Mr. Campbell saw him frequently, and was at the dinner given to the distinguished visitor at the Reform Club.

Soon after his return from Italy, in 1860, Mr. Campbell met and married Miss Ellen Cottingham. They had only one child, a daughter. His wife's health being delicate, he left his residence in Kilburn about four years after his marriage, and went to live in the country. Barnet, in Hertfordshire, was the place finally settled on, and there he bought Arkley House, where he lived many years.

In 1865 Mr. Campbell was a candidate for Chester, but was unsuccessful. Political life was not altogether to his taste, and he soon relinquished all attempts in that direction.

What he most loved was science of every kind, but particularly the science of mathematics. He soon became so absorbed by astronomy that in 1877–78 he built the Arkley Observatory, and devoted himself to astronomical matters. In conjunction with Mr. Neison (now Mr. Neville-Nevill, of the Durban Observatory, Natal) he worked for several years at the Lunar Theory. The first joint paper by Campbell and Neison appears in *Monthly Notices*, vol. xl. pp. 386–411 and 441–472, and is entitled "On the Determination of the Solar Parallax by means of the Parallactic Inequality in the Motion of the Moon." After discussing at length previous observations available for this purpose, the authors conclude that the chief systematic errors affecting these observations can be avoided by observing transits of a small crater on the Moon instead of the limb, and declare their intention of making a series of observations on the crater Murchison A. This work was commenced at the Arkley Observatory in 1879 April, and in that year twenty-one observations were obtained. In 1880 fifty-three were added, in 1881 another fifty-three, and others (not specified) in 1882, the report in 1883 February being the last received by this Society from the Arkley Observatory.

Since his removal to Natal, Mr. Neison [Nevill] has carried on these observations and the work of reducing them, and in the report of the Natal Observatory for 1892 February he writes: "The final touches are also being put to the discussion of the observations of the position of the lunar crater Murchison A, made at the Arkley Observatory in the years 1879–1884, and at the Natal Observatory during the years 1883–1886."

In 1885, for various reasons, Mr. Campbell broke up his work and left Arkley. Shortly before he left he began to give much time and study to mechanical inventions. Among other patents taken out by him was a very ingenious ship's log, which showed on a dial on board the exact speed of the ship from time to time.

From Arkley he went to live at Bush Hill Park, Enfield, and in 1888 he again removed, to Strawberry Hill, Twickenham, to be near his daughter and her husband. There in 1892 June his wife died. Mr. Campbell felt his loss acutely, and never entirely recovered either health or spirits, though up to this time he had been a man of robust constitution, singularly simple in tastes and habits. In 1894 December he caught a severe cold, which ended in influenza and severe bronchitis, and after a painful illness of a few days he passed away on December 11 in his seventy-third year.

During his latter years Mr. Campbell bore many severe trials with wonderful patience and fortitude, and these, instead of souring or embittering, seemed to show up more strongly the sterling qualities of his mind and nature. To the last he retained his devotion to learning and science and his wonderful love for animals, especially dogs. For over forty years he possessed a very fine breed of Newfoundlands. Several generations had been his loved companions; he was never without one or two wherever he went. "Mr. Campbell's great dogs" were as well known as himself.

[For many of these particulars the Council is indebted to Mr. Campbell's daughter, Mrs. Campbell-Heap.]

Arthur Cayley was the second son of Henry Cayley, a Russia merchant settled at St. Petersburg. He was born at Richmond, Surrey, on 1821 August 16, during a short visit of his parents to this country. The family returned permanently to England in 1829, and after a time fixed their residence at Blackheath, Kent. He was sent to a private school at that place, kept by the Rev. G. B. F. Potticary, and at the age of fourteen he went to King's College School, London. He came up to Trinity College, Cambridge, in 1838, and graduated in 1842 as Senior Wrangler and First Smith's Prizeman. It has often been the subject of remark that four such distinguished mathematicians as Leslie Ellis, Stokes, Cayley, and Adams should have been senior wranglers in four successive years.

Cayley was elected Fellow of his college in the year in which he took his degree, and was assistant tutor for about three years. As he did not take holy orders his fellowship was only tenable for a limited term, and it was necessary for him to select a profession. He chose the Bar, and about 1847 he became a pupil of the eminent conveyancer, Mr. Christie. He was called to the Bar in 1849, and during the time that he practised was always supplied by Mr. Christie with as much conveyancing work as he was willing to undertake.

As an undergraduate he had shown very marked mathematical ability, and had already published two or three papers in the *Cambridge Mathematical Journal* at the time of the examination for his degree. The *viva voce* part of the examination still existed then, and Mr. Gaskin, the Senior Moderator, told him that he was acquainted with his papers and need ask

him no questions. During the time in which he resided at Cambridge after his degree, and while at the Bar, he was incessantly occupied with mathematical investigations, and it was during this period of his life that some of his finest work was produced.

Certain lectureships on algebra, tenable for ten years, in each of the colleges at Cambridge were founded by Lady Sadler at the beginning of the last century, and had existed from 1710 till 1860. In the latter year a statute was sanctioned which enacted that after that date no more lecturers were to be appointed, and that when so many vacancies had occurred that not more than one-half of the net income of the foundation was required for the payment of the remaining lecturers a Sadlerian professorship of pure mathematics was to be established. The requisite number of vacancies occurred in 1863, and Cayley was elected the first Sadlerian professor. He willingly gave up the prospect of great legal eminence in order to devote his whole time and thought to his favourite subject, and at once returned to Cambridge. Perhaps no professorship was ever founded more opportunely.

There is scarcely any department in the whole range of mathematical literature which was outside the field of Cayley's work, and even among the minor subdivisions of mathematics it is difficult to think of a subject which did not claim his attention at some time in his life. He was a most prolific writer, and probably equalled Euler in versatility and facility of production. The regions most extended by his labours were, perhaps, Algebra, Analytical Geometry, and the Integral Calculus, but he also contributed largely to the Theory of Numbers. About 1856, when he had already published more than 150 papers on subjects relating to pure mathematics, he seems to have been attracted to dynamics and elliptic motion, for in that year he contributed a paper on the "Theory of Elliptic Motion" to the *Philosophical Magazine*, and his report on the "Recent Progress of Theoretical Dynamics" appeared in the *Report of the British Association* for 1857. He also wrote a paper on "Hansen's Lunar Theory," in the *Quarterly Journal of Mathematics* for 1857, and (in the same volume) a note on "Jacobi's Formulæ for Disturbed Motion in an Elliptic Orbit." He was elected a Fellow of our Society on 1857 July 10, and during the next few years communicated several elaborate memoirs relating to the development of the Disturbing Function, which were printed in vols. xxvii.–xxxi. of the *Memoirs*. When Adams's value of the secular acceleration of the Moon's mean motion was so strenuously controverted by Pontécoulant and others, Cayley undertook an independent calculation of the coefficient of the term in dispute, his result confirming Adams's value. This paper was printed *in extenso* in the *Monthly Notices* for 1862. Cayley's subsequent communications to the Society were numerous; but, with the exception of the papers relating to Delaunay's lunar theory, they may be said to have related chiefly to mathematical questions

that fell within the domain of astronomy rather than to astronomy itself. For example, the elaborate memoirs on the determination of the orbit of a planet from three observations, and on the geodesic lines on an ellipsoid, contain little that concerns even a mathematical astronomer, unless he were also interested in pure mathematics. It may here be mentioned that projections and graphical methods always had a special attractiveness for Cayley; his inclination towards these subjects is shown in several of his papers published by the Society.

In 1859 December he became the editor of the publications of the Society, in succession to Mr. Grant, who had been appointed Professor of Astronomy at Glasgow. The *Monthly Notices* and *Memoirs* were edited by him continuously from that time until 1882, except during the two years of his Presidency, 1872–74, when the editorship was undertaken by Mr. Proctor. Cayley was a Member of Council from 1858 until 1893, and during nearly the whole of that period he was a regular attendant at the meetings.

The duties of the Sadlerian professor were "to explain and teach the principles of pure mathematics and to apply himself to the advancement of that science." Cayley delivered one course of lectures in the Michaelmas term of each year until the professorship was placed under the new statutes in 1886, after which he lectured in the Lent term also. The teaching work attached to the professorship was therefore very small, and he was free to devote his whole energies to the advance of his subject. How splendidly he availed himself of his opportunities is shown by his writings, which have influenced every branch of mathematics. In mere extent they are very considerable, exceeding 800 in number.

It is difficult to do adequate justice to Cayley's merits as a mathematician, so great and varied were his powers and so wide the range of subjects to which they were applied. It is, perhaps, as one of the principal founders of the modern higher algebra that his name is best known. It is forty years since these notable researches of Cayley and Sylvester followed each other in such quick succession. Salmon also bore a part, and it was by his well-known treatise that the newly-discovered subject was rendered available to students. With the exception of quaternions, this is the only branch of mathematics which this country can claim the honour of having originated and developed. Cayley's great memoir on elliptic functions, in which they were derived from the doubly periodic products, appeared as long ago as 1845. He also made other important contributions to this subject, being especially interested in the algebraical theory of transformation and the modular equations. The theories of curves and surfaces were greatly extended by his labours. Reference should also be made to the geometry of n dimensions, which frequently occupied his attention at all times in his life. The only separate book published by him was a treatise on *Elliptic Functions* which appeared in 1876.

The republication of Cayley's collected papers was undertaken by the Cambridge University Press in 1889, and seven volumes, containing 485 papers, had been issued under his own editorship at the time of his death. Since then two additional volumes, carrying the papers down to 1877, have been issued under the editorship of Professor Forsyth. The number of papers contained in the nine volumes is 629, and it is announced that the completed works will probably extend to thirteen volumes. Some idea of the mass of work published by Cayley may be obtained when it is stated that each volume is a quarto of 600 or more closely printed pages.

With respect to the character of Cayley's work, it is scarcely possible to exaggerate his immense grasp over the analytical processes. As an algebraist it is probable that he has never been surpassed. He seemed able to apply algebraical methods to every kind of subject with masterly success, and to possess the gift of discovering the right "handle" wherewith to take hold of a subject, so to speak. An extraordinary command over the management of symbols, and a penetrating insight into the truths that underlay the formulæ, were perhaps the most conspicuous of the qualities which enabled him to do lasting work in every branch of mathematics. In preparing his work for publication Cayley seemed to care only for the substance, attaching but little importance to elegance of form or simplicity of development. He made no attempt to exhibit his results in their most attractive form; in fact, when he had been occupied on a subject for some time, he would frequently put together the work he had done pretty much as it stood, and send it for publication. He always printed his investigations as he did them, and at no time were there any considerable accumulations. We owe it to this habit that he has left no arrears of unfinished work.

His power of entering into the researches of others was hardly less remarkable than his wonderful capacity for original work. By merely "dipping into" a difficult foreign memoir he was able to seize the meanings of the symbols and comprehend the principal results without reading the investigation itself. The theorems which he had thus mastered he would frequently prove by a method of his own (generally algebraical), almost always carrying the investigation further. This gift of almost instantaneously grasping and seeing in a new light the results of others contributed in no slight degree to increase the great reputation his writings had won him on the Continent. As regards the nature of his own work, he was essentially a great explorer; he loved to explore anywhere, and he was always tempted by any newly discovered territory. This universality of his tastes, and his great fertility, are very remarkable characteristics. He had no liking for the philosophy of mathematics, and did not care much to contemplate existing knowledge, or dwell upon what he had accomplished himself. Each new result would seem to have presented itself to him principally as a fresh point of departure for

new investigations. He was fond of making *résumés* of work done on a special subject, but his object generally was to clear the ground for future research.

Cayley's lectures almost invariably related to a subject upon which he was then engaged, and the lectures themselves sometimes contained the results of work done since the preceding lecture. For example, the paper already referred to, on the determination of the orbit of a planet from three observations, formed the subject of one of his courses of lectures before it was completed and presented to our Society. He did not give the same course of lectures twice, nor did he ever prepare a course of lectures distinct from work that was occupying his attention at the time. The general expression of his views on any branch of mathematics and his mode of work were interesting; but he had not the art of teaching, nor was the matter or arrangement of his lectures suitable for those who were previously unacquainted with the subject. The attendance was small, and the lectures did not form part of the ordinary course of mathematical study in the university. He was a good correspondent, and to letters asking for information on mathematical questions he always returned full and prompt replies. A vast number of mathematical papers submitted to scientific societies were referred to him; and in all such cases he was an admirable referee. He had a clear and definite idea of the standard of excellence—not an unduly high one—that should be maintained, and his reports were always valuable and practical.

After 1863 he spent the remainder of his life in Cambridge, principally occupied by mathematical research. He undertook, however, a very considerable amount of voluntary work for bodies with which he was connected. He freely placed his time, legal knowledge, and skill at the disposal of his university and college, and of the scientific societies to which he belonged. The present statutes of Trinity College, Cambridge, were principally drafted by him, and during the years in which he was one of the members of the Council of the Senate he undertook a good deal of work of the same class for the university. One of the last services of this kind which he performed was the drafting of the regulations of the Isaac Newton studentships, founded by Mr. McClean in 1890. On councils, or committees, or syndicates in the university he was always one of the most valued members. He spoke only when he had something of importance to say, and was always listened to with respect. He was perfectly fair-minded, and possessed a sound judgment and a temper that could not be ruffled. Though conservative in most matters, he was free from general political bias. At the elections to the Council of the Senate at Cambridge he was usually nominated by both parties, and in other cases, where there was a conflict of opinion he was invariably supported by all sides. He was retiring in disposition and very shy in manner, though less so in the latter part of his life. He was singularly unfitted for party strife in any form, and was

always unwilling to concern himself with the conduct or motives of others. His character, however, was a strong one, and he never allowed himself to swerve from what he believed to be his duty. He was businesslike in the affairs of ordinary life, and everything that fell to him to do was well and punctually done. He took a special interest in matters relating to finance, and only a few months before his death published a pamphlet on book-keeping. He steadily supported the movement for the promotion of the higher education of women from the first, and for some years was Chairman of the Council of Newnham College.

He was a good linguist, and was an eager reader of fiction all through his life. He was also interested in painting and architecture, and derived much comfort from his acquaintance with these subjects in his long and wearisome illness. He was very fond of walking up to the last few years of his life, and took an especial delight in mountain scenery. Although not social in the ordinary sense of the word, he was not a recluse, but liked the society of his friends, who were always welcome to his house.

He was President of the London Mathematical Society, 1868–70, of the Cambridge Philosophical Society, 1869–71, and of the British Association at the Southport meeting in 1883, on which occasion the subject of his presidential address was the progress of pure mathematics. When he was President of our Society in 1874 he delivered the address in presenting the gold medal to Professor Simon Newcomb. He was elected Fellow of the Royal Society in 1852. In 1872 he was elected honorary Fellow of Trinity College, and in 1875 he was re-elected an ordinary Fellow, a position which he retained for the remainder of his life. In 1882 he accepted an invitation from the Johns Hopkins University, Baltimore, to give a course of lectures during the winter session. These lectures were delivered in the first five months of 1882.

The honours he received were almost as numerous as could fall to the lot of any scientific man. Degrees were conferred upon him by the Universities of Oxford, Dublin, Edinburgh, Göttingen, Heidelberg, Leyden, and Bologna; and in 1888 he received, in conjunction with Stokes and Adams, the honorary degree of Sc.D. from his own university. He was an officer of the Legion of Honour; a foreign associate of the French Institute, and of the Academies of Berlin, Rome, and other cities. He received the Copley and Royal Medals from the Royal Society, the De Morgan Medal from the London Mathematical Society, and the Huyghens Medal from Leyden. His portrait was painted in 1874 by Mr. Lowes Dickinson, and presented by the subscribers to Trinity College, where it now hangs in the hall. A reproduction of this portrait appeared in the sixth volume of his collected works, and a sketch, made at the same time by Mr Lowes Dickinson, was prefixed to the seventh volume. There is also a bust of him in the library of Trinity College.

Towards the end of 1892 his health began gradually to fail, and he had occasional attacks of severe illness, which confined him to his bed for weeks together, each leaving him weaker than before. One of these attacks occurred on 1895 January 8, but he seemed to be getting better, when on January 21 he began to grow rapidly weaker, and died about six o'clock on the evening of Saturday, January 26. He was interred at Cambridge on the following Friday, the funeral service taking place in Trinity College, when the large assemblage of senior members of the University, of the representatives of Governments and societies, and friends from a distance, testified to the respect and estimation in which he was held.

In 1863 he married Susan, daughter of Robert Moline, of Greenwich. His wife and two children survive him. His valuable mathematical library has been presented by Mrs. Cayley to Trinity College and Newnham College. J. W. L. G.

Edward John Collingwood was born on 1815 February 4, at Chirton House, North Shields. His residences were Lilburn Tower and Chirton House, but he sold the latter some years ago. He built an observatory at Lilburn Tower about the year 1852, in which he placed a $6\frac{1}{3}$-inch refractor, equatorially mounted, and a 4-inch transit instrument; but his eyesight failed shortly after the instruments were mounted, and he was unable to do much astronomical work.

He married in 1842 Anna, daughter of the late Arthur Burdett, of Co. Tipperary and King's County, by whom he had issue three sons and two daughters, all of whom survive him. He died at Lilburn Tower on 1895 February 20. Mrs. Collingwood died in 1879.

He was elected a Fellow on 1851 February, but contributed no papers to the Society.

[For these particulars the Council is indebted to his son, Mr. Edward J. Collingwood.]

Richard Dunkin was born at Truro on 1823 June 9. He was the fourth and youngest son of Mr. William Dunkin, who was for nearly thirty years one of the established computers of the old edition of the *Nautical Almanac*, and afterwards a member of the staff of the *Nautical Almanac* office, on its reorganisation in 1831 under the direction of Lieutenant Stratford, R.N., F.R.S. R. Dunkin received his general education at private schools at Truro and Camden Town, London, and finally at a well-known French school at Guines, near Calais, where he remained until the death of his father in 1838 July. In the following month, August 21, through the recommendation of Mr. Davies Gilbert, F.R.S., a Past President of the Royal Society, and Lieutenant Stratford, he and his elder brother were engaged by the Astronomer Royal for special employment in a new department of the Royal Observatory, then recently established

by the late Sir G. B. Airy for the systematic reduction of all the planetary and lunar observations made at Greenwich between the years 1750 and 1830. Richard Dunkin was employed nine years on these laborious calculations, first on the planetary section, and after 1841 on the lunar sections of this important work, the whole of which was carried on in the Octagon Room by a large number of computers. In 1847 August he was appointed an assistant in the *Nautical Almanac* office, on the staff of which he continued a member thirty-six years, retiring in 1883 on a Civil Service pension as a first-class assistant. He had thus an unbroken official service of forty-five years.

When in 1838 R. Dunkin joined the computing staff at the Royal Observatory, the office hours in this special department were excessively long, usually from 8 A.M. to 8 P.M., with only a relaxation of one hour for luncheon at midday. In 1839 the computing-day was reduced to eight hours. The close application required during eleven hours, and even eight hours, without a chance of any variation of work, was almost too great a strain on the nerves of a delicate youth of fifteen. It was, therefore, no wonder that this severe sedentary occupation, coming so soon after the comparative freedom of school-life, unfavourably affected both his bodily and mental health, causing at one time much anxiety to his relatives. There can be no doubt that it was owing principally to this close confinement to the desk in his early years, at a critical period of his life, and also partly on account of his naturally reserved and retiring disposition, that he never felt disposed to undertake any astronomical calculations outside his office, fully believing that it was necessary to reserve all his strength strictly for his work at Verulam Buildings. For many years, however, he took a considerable interest in astronomical questions, and in the general progress of the Society, although he never contributed a paper to its Proceedings. He was also well-informed on several other branches of science, having some acquaintance with experimental chemistry and photography, and also of botany and its scientific classifications, and he had a fair knowledge of general scientific history and literature. He had a great love for French poetry, a taste he acquired during his school-days at Guines, and he was also gifted with a remarkable memory for past events. All these pursuits afforded him a most agreeable pastime during the leisure hours of a considerable portion of his life, but more especially between the years 1848 and 1861.

In the autumn of 1884, about a year after his retirement from the *Nautical Almanac* office, Mr. R. Dunkin went to reside at Truro, in the house in which he was born. Here he passed the remainder of his life in the quiet enjoyment of the study of his favourite subjects, so far as his declining health permitted. During his later years he also took a great personal interest in floriculture, and was very successful in the cultivation of many choice specimens of flowers. He was never married. For a

long time he had been subject to an occasional partial failure of the heart's action. From these attacks he generally soon recovered, but after only a few days' illness from one more severe than usual, aggravated by the intensely cold weather of the winter of 1894–95, he passed away peacefully on the morning of 1895 February 19, in the seventy-second year of his age. He was elected a Fellow of the Society on 1851 June 13. E. D.

SIR CYRIL C. GRAHAM, of Kirkstall, was born in 1834. In 1874 he married Louisa Frederica, daughter of the late Rev. Lord Charles Hervey, D.D. Early in 1857 he made a long journey into the higher and less known regions of the Nile, and was rewarded by the discovery of several inscriptions of value. Next he travelled very carefully over the greater part of Palestine and much of Syria. In August 1857 he made explorations of great interest in the desert east of the Haurán and in the land of Bashan, where he discovered very curious inscriptions.

Respecting this last expedition he communicated valuable papers to the Royal Geographical and Asiatic Societies, of both which he was a member.

For the Transactions of the Royal Society of Literature he wrote a further paper on "Additional Inscriptions from the Haurán and the Eastern Desert of Syria," which was edited with a preface and notes by John Hogg, London, 1859.

In 1860-61 he was attached to Lord Dufferin's Mission in Syria (having previously travelled with him in that country in the autumn of 1859) as private secretary. In respect of his services in this capacity Lord Dufferin thus expressed himself: "At the expiration of about nine months our task was successfully terminated; the Constitution then drawn up has ever since rendered the Lebanon the best governed territory in the Turkish possessions. To these results he [Sir Cyril] powerfully contributed. . . . His abilities were certainly extraordinary. He had a peculiar talent for languages, and a most remarkable memory. As for his engaging qualities, they were innumerable."

In 1870–71 he went on behalf of the Hudson's Bay Company on a special mission to Canada and Hudson's Bay Territory to negotiate arrangements between the Company and the Government of the Dominion.

In 1873 Sir Cyril travelled in Russia, from Archangel to Astrakhan, and from the White Sea to the borders of the Kaspian, passing homewards through Daghistan and Georgia. Here, in the Caucasus, his attention was turned to the peculiarities of the Lesghian or Avâr language, on which he communicated a paper of great value to the Royal Asiatic Society in 1881.

In 1875–77 he was Lieutenant-Governor of Grenada in the West Indies, where he succeeded in bringing about an important change in the Constitution, which had previously been found unsatisfactory in its working.

He was a member of the Geological Society. He was an accomplished linguist and philologist, being a master of Arabic and Turkish, well versed in Ægyptology, speaking French, German, and Italian like a native, and knowing much of several other tongues.

Of the Royal Geographical Society he was Foreign Secretary from 1866 to 1871. He succeeded his brother, Sir Lumley Graham, in the Baronetcy on 1890 October 25. He died on 1895 May 9.

[For the above particulars the Council is indebted to Mr. Dudley Hervey, C.M.G., brother-in-law of Sir C. C. Graham.]

JOHN RUSSELL HIND was the son of Mr. John Hind, of Nottingham, lace manufacturer, and was born at Nottingham on 1823 May 12.

He was educated privately and at the Nottingham Grammar School, and at the age of seventeen was sent to London as an assistant to Mr. Carpmael, civil engineer, for which profession he was intended.

But for some years previously he had studied astronomy, of which he soon became an enthusiastic devotee. When he was but sixteen years of age he contributed a number of astronomical notes to the *Nottingham Journal* and other newspapers.

He only remained in Mr. Carpmael's office a short time, his prevailing tastes drawing him still further towards his favourite study, and at the end of the year 1840 he secured, through Sir C. Wheatstone, a post at the Royal Observatory, Greenwich, Mr. Airy, then Astronomer Royal, appointing him to the Magnetical and Meteorological Department. He remained at the Observatory till 1844.

In 1843 he was engaged for a period of three months on the Commission appointed by the Government to determine the longitude of *Valentia*.

On leaving Greenwich he was appointed observer at Mr. Bishop's private observatory in Regent's Park, London, and there he made those discoveries which have rendered his name famous, including 10 new minor planets and 3 comets, besides variable stars and nebulæ. For these discoveries he received one of the twelve testimonials of our Society on that well-known and exceptional occasion in 1848, when these testimonials were to be considered "equivalent to a Gold Medal"; and, further, the Gold Medal actually in 1853. He also received, in 1851, 100*l*. from the Royal Bounty Fund, and in 1852 was granted a pension from the Civil List of 200*l*. per annum "in consideration of his contribution to astronomical science by important discoveries."

In 1851 he went with Mr. Dawes to Sweden to observe the total eclipse of the Sun.

On the death of Lieutenant Stratford, in 1853, Dr. Hind was appointed Superintendent of the *Nautical Almanac* office, which position he held till his retirement under the superannua-

tion scheme in 1891. He continued to exercise a general superintendence over Mr. Bishop's observatory, the actual observers being in succession Mr. Norman Pogson, Dr. Vogel, Mr. Marth, and Mr. Talmage; and on the death of Mr. Bishop in 1861, when his son, George Bishop the younger, removed the instruments to Twickenham, Dr. Hind remained in charge.

Since his retirement in 1891 from the *Nautical Almanac* office Dr. Hind lived quietly at Twickenham, not appearing much in public, nor even visiting the societies to which he belonged; but he still kept up a lively interest in his favourite study, and was a regular subscriber and contributor to the scientific journals at home and abroad. He died at Twickenham, on December 23, 1895, of heart-disease accelerated by a chill, and was buried at the Twickenham Cemetery.

The number of minor planets is now, at the close of this eventful century, which opened with the discovery of the first of them, so large that it is difficult to realise the interest excited by the new discoveries half way through it in which Dr. Hind played so important a part, an interest which would doubtless have been greater still but for the overshadowing of the sensational discovery of *Neptune*. A few of the leading facts may be fitly here recalled; but a glance through our *Monthly Notices* of the period will give a far better idea of these exciting times.

The succession of discoveries was so rapid that a few dates are important. Hencke discovered *Astræa* (5) on 1845 December 8, as the result of a patient search for minor planets, continued during 15 years unrewarded, and after an interval of nearly 40 years since the discovery of the first four. *Neptune* was discovered on 1846 September 23. On 1847 July 1 Hencke discovered *Hebe* (6); and a few weeks afterwards Hind found *Iris* (7), and followed with *Flora* (8) before the end of the year.

Hind's discoveries, like those of Hencke, were the result of a patient search with the definite object of finding minor planets. Mr. George Bishop had determined before building his observatory that it "should do something." A successful business man, he had always had a great wish to possess an observatory, but never the opportunity until he was more than fifty years of age; and being then unable to work personally, he took great pains to get good assistants, and set them to observe with a definite object. "The search for minor planets was commenced in 1846 November, employing the Berlin star maps" (to which attention had doubtless been attracted by the discovery of *Neptune* two months before) "as far as they extended, small stars of 9·10 or 10th magnitude, not marked on the maps, being inserted from time to time as they came under examination."

The first discovery was announced to the Rev. R. Sheepshanks, then vice-president of our Society, in the following letter:—

"3 Allsop's Terrace, New Road, London:
"1847 August 13^d 16^h.

"DEAR SIR,—I have this night discovered another member of the singular group of planets between *Mars* and *Jupiter*. It shines as a star of 8·9 magnitude, the observed positions being—

	G.M.T. h m s	R.A. h m s	δ ° ′ ″
Aug. 13 at	9 35 17	19 57 30·52	−13 27 23·4
	10 45 19	19 57 28·02	−13 27 29·0

showing a retrograde motion in R.A. of 51^s daily. Have I been fortunate enough to detect the lost planet of *Cacciatore*?

"Yours very respectfully,
"J. R. HIND.

"Rev. R. Sheepshanks, M.A."

The discovery of *Flora* on October 18 was also announced to Mr. Sheepshanks by a letter written the same night at 16^h, giving three positions for $11^h\ 40^m\ 4^s$, $15^h\ 4^m\ 10^s$, and $15^h\ 52^m\ 27^s$ respectively.

These two discoveries were rewarded, as remarked above, by a "Testimonial." The exact significance of the term may have been forgotten by some, perhaps by many. The fierce controversy regarding the discovery of *Neptune* paralysed the action of the Council in 1847: they could not decide whether to give the medal to Adams, or to Le Verrier, or to both, and accordingly made no award at all. This course, however, did not remove, but only deferred, the difficulty. The action of the Council was criticised at the time, and as the next annual meeting approached it was felt that the question must still be dealt with. Attempts were made at evasion by advancing the claims of others, of whom Hind and Hencke were put prominently forward. Among the Sheepshanks letters, preserved in our library, there is one of great interest, bearing as it does the signature J. C. Adams, and dated 1847 December 10:—"My counsel would be," writes Professor Adams, "to give a medal each to Hencke and Hind. I think two planets each establish a fair claim. Now is the time to give them. Medals might be given to Sir John Herschel and M. Hansen next year. No one looks upon their works with more respect and admiration than myself, but it would be no slur upon them to give the medals this year for such a widely different department of science, not at all coming into competition with either of their subjects." Nothing could be more characteristic of the great man we lost a few years ago than this anxiety to have his own claims put aside, nor more effective in indicating the estimation in which the discoveries of Hencke and Hind were held in this eventful period.

The solution of the difficulty arrived at was the award of Testimonials "in place of and in the same rank with the usual Medal" to twelve persons, including Adams and Le Verrier,

Hencke and Hind, Sir John Herschel and M. Hansen, and, it may be remarked, Mr. George Bishop, who had founded the observatory where the planets were discovered. Of these twelve, Dr. Hind was at his death the sole survivor; nor is there now alive any member of the Council which dealt with these burning questions. The expedient of a Testimonial has never since been resorted to.

It fell to Sir John Herschel, himself one of the recipients, to deliver the address on the merit of those who received Testimonials. In speaking of Dr. Hind he remarked: "No name comes oftener before the astronomical world, as an assiduous observer and able computist in the department of astronomy which the nature of the instrumental means committed to his charge gives him an immediate connection with, as a diligent observer of double-stars and computer of their orbits, for instance, or as the first detector of several comets, one of them a very remarkable one, which, from his calculation of its orbit, he was enabled to follow up to its actual perihelion, and to behold it at noon-day presenting a clear and well-defined disc within 2° of the Sun."

This sentence reminds us that even before the discovery of *Iris* and *Flora*, Dr. Hind was already a discoverer of comets and an astronomer of distinction. He was also Foreign Secretary of our Society.

In 1853, when the number of his planetary discoveries had been increased to eight, Hind received the Gold Medal itself from the hands of Adams. After this he found two more planets; but the list closed when he settled down at the *Nautical Almanac* Office in 1854.

One or two circumstances connected with the naming of the early discoveries may be noted here. The name *Iris* was proposed by De Morgan, who also suggested a symbol. Writing to Sheepshanks (1847 August 22) Hind says, "I find the name is approved at Cambridge and Greenwich, though *Thetis* was preferred. However this will do for the next, if no better is to be found." The name *Thetis* was not, however, used till the discovery of (17) by Luther in 1852.

On the discovery of (12) in 1850, the Americans strongly objected to the proposed name *Victoria*, which happened to be also that of our Sovereign. Indeed, they went so far as to substitute *Clio*, and the Astronomer Royal wrote, "When I looked for *Victoria* in the index to *Gould's Journal* and expected at least to find '*Victoria*—see *Clio*,' and found it not, I was very indignant." At the same time he advised Dr. Hind not to use the name *Clio* for a subsequent discovery in 1852, which "would cause much confusion and would be interpreted as exhibiting a too angry temper." The name *Clio* had been apparently suggested by Adams, or at least approved by him. "*Clio* is the name which I should have preferred," he writes, "but since Mr.

Airy so strongly objects, and others may perhaps take the same view, it is perhaps better not to risk the breaking of unanimity ;" and he goes on to suggest *Calliope.* The choosing of this name was attended with more than ordinary interest, since the planet had been discovered on the morning of the Duke of Wellington's funeral ; hence the name of *Calliope*, "whose office in ancient mythology required her to perpetuate the illustrious deeds of heroes." The rejected name *Clio* was not used till the discovery of (84) in 1865 (curiously enough by Luther, who had previously appropriated the rejected name *Thetis*).

Besides minor planets and comets, Hind discovered two objects of conspicuous interest—viz., the "new star" in *Ophiuchus* ; and the variable nebula in *Taurus*, the variability of which has been recently confirmed by Barnard and Burnham. His following of a comet into full sunshine has already been mentioned in the words of Sir John Herschel. His prediction of the "return of the Great Comet of 1264 and 1556" was not so successful, minuter examination showing that perturbations vitiated the results. The prediction appeared in the *Monthly Notices*, and also in a separate work. Of other works on Astronomy by him the chief are *The Solar System*, *Recent Comets and the Elements of their Orbits*, *An Astronomical Vocabulary*, and a *Descriptive Treatise on Comets*. His list of scientific papers is a very long one, and he contributed to many periodicals.

Dr. Hind was elected a Fellow of this Society on 1844 December 13. At the same meeting was elected as an Associate Signor Cacciatore, whose "lost planet" Hind had been inclined on the night of discovery to think that *Iris* might be. At the preceding meeting Sir John Herschel had read his memoir on Francis Baily, who had died while President for the fourth time ; but although the date of Dr. Hind's election thus links us with the foundation of our Society, three of our present Fellows were elected before him. In 1846 he was placed on the Council, and in 1847 he succeeded Sir John Herschel as foreign secretary, which position he retained till 1857. In 1880 he was elected President, and he presented the medal to Dr. Axel Möller and to Dr. Gill. It is proper to mention here the work Dr. Hind undertook for the Society in superintending the comparison of Hansen's and Burckhardt's tables of the Moon for the years 1847–1865, published as an appendix to vol. l. of our *Monthly Notices*.

In 1847 he was made a corresponding member of the Société Philomathique of Paris. In 1850 he was one of a Commission, for the Exhibition of 1851, respecting machinery as applied to direct use. In 1851 he was elected a corresponding member of the Academy of Sciences of Paris, in the place of Schumacher. There were eighteen candidates for the election, Dr. Hind being chosen by forty-five out of forty-six votes. The same year he was made a Fellow of the Royal Society, and subsequently he was elected into the Royal Society of Edinburgh, the Imperial

Academy of Sciences of St. Petersburg, and the Swedish Royal Society (Lund). He was also made Hon. LL.D. of the University of Glasgow. He was the recipient of many medals, the chief of which were the gold medal of the Royal Society, the gold medal of the Royal Astronomical Society, a gold medal from the King of Denmark, six times the Lalande medal (with money prizes amounting to over 60*l.*), and a medal from the French Institute, struck to commemorate the discovery of one hundred minor planets, in 1869. The obverse of this medal consisted of the profiles of the Englishman, the Frenchman, and the German, who had discovered most of these planets, the Englishman represented being Dr. Hind.

It is curious that during the years of his greatest activity (1844–1856) Dr. Hind suffered from extreme bad health. Physically he was apparently a strong man, but he was excessively nervous and frequently had to give up work for a time on account of "excessive nervous exhaustion." He was of a most retiring disposition, and worked more for science' sake than for the approbation of his fellow-men or for his own pecuniary advancement. In his diary, under date 1849 January 15, he wrote, "I mentioned to Mr. Airy to-day that I thought very soon I should have to relinquish observations at night entirely," but happily a few months' rest enabled him to resume work and complete the task he had set himself to do.

He married in 1846 and had six children. For the personal details of the above notice, and for much valuable assistance, the Council is indebted to his son, Mr. T. Almond Hind.

Frederick Robert Hughes was born in London on 1807 November 29. His father was a clergyman, and volunteered as a missionary to Sierra Leone; but both he and his wife died soon after their arrival, and their son returned to London, where he was brought up under the care of an uncle. He received a liberal education; and when a young man held an appointment in a chemical manufactory till 1830, when he removed to Borrowstowness, in Scotland, and very soon afterwards went into partnership for the manufacture of prussiate of potash, to which was subsequently added that of iodine from kelp. After a prosperous business career he retired in 1877. He enjoyed good health until within about a year of his death, at Borrowstowness, on 1895 March 11. His wife died in 1840, but a daughter (the wife of Colonel Harwood, of Sanday, Orkney, to whom the Council is indebted for this notice) survives him.

He was deeply interested in science, especially astronomy, optics, and mathematics, and had numerous appliances specially constructed for him. He possessed a fine equatorial by Cooke, and many other instruments.

He was elected a Fellow on 1866 January 12, but contributed no papers to the Society.

Captain A. Lister Kaye was born at Denby Grange, near Wakefield, on 1834 May 12. He entered the Royal Artillery and served in the Crimea, for which he received the Crimean Medal and Turkish Clasp of the Order of the Medjidie. He was also twice with his regiment in India. He left the Army in 1865 and lived at the Manor House, Stretton-on-Dunsmore, Rugby, till his death on 1893 December 5. He married in 1867, and leaves a widow, two sons, and three daughters.

He possessed a 4-inch refractor by Cooke, and a transit, and observed sun-spots and double stars.

He was elected a Fellow in 1882 November, but contributed no papers to the Society.

[For the above particulars the Council is indebted to Mrs. Lister Kaye.]

Arthur James Melhuish was born in London in 1829. In 1853 he married Caroline Powell, of Tiverton, Devonshire, by whom he had seven children—three sons and four daughters. He lived for some years at Blackheath, but came to London in 1863, and resided for many years at 12 York Place, Portman Square (the house formerly occupied by William Pitt). He died at Brondesbury on 1895 November 1. In 1873 he started, in conjunction with Mr. Alfred Wilcox, the *Church of England Pulpit and Ecclesiastical Review*, which is still carried on, though now in other hands. He is the author of a work on "Mental Analysis," and of many papers published in various magazines—"The Geology of the Bible," "Truth about Ghosts," "Good Fools," &c.

He was elected a Fellow in 1863 January, but contributed no papers to this Society. He was an Honorary Fellow of the Meteorological Society.

[For the above particulars the Council is indebted to Mr. A. Newton Melhuish, son of our deceased Fellow.]

Oluf Andreas Löwold Pihl was born 1822 December 5 in Stavanger, Norway, where his father was a merchant. Mechanical ingenuity has been characteristic of several members of this family. Oluf Pihl's grandfather, a country clergyman at the close of the last and the beginning of this century, was not only an astronomical observer, but had in his residence in Hedemarken, near the lake of Mjösen, a real workshop for clocks, speculum-telescopes, and other astronomical and physical instruments. The University Observatory in Christiania is in possession of some instruments of his making, *e.g.* an artificial horizon of glass, with level, and a clock with gridiron pendulum, which is still in use in the meteorological room of the Observatory, and has several times been used as an electrical transmitter for coincidences of clock signals in longitude determinations. A box chronometer, used by Oluf Pihl for his astronomical observations, was also of his grandfather's making.

Oluf Pihl's mechanical abilities having made their appearance in early boyhood in the usual manner by his taking watches to pieces and putting them together again (his first positive enterprise in this way was to put a new spring in the watch of a fellow-schoolboy who had dropped it in the street, but dared not tell the misfortune to his father), he was sent to England to be an engineer. Here he made the acquaintance of a Norwegian engineer, Mr. Sörensen (later on for many years director of the mechanical works of the Royal Norwegian Navy), and of a Swedish Count Rosen, an amateur engineer, who had formerly taken part in the Greek War of Independence, and was then living in London. By their advice he went to Sweden, after a year's stay in England, to obtain the necessary theoretical training at a technical school in Gothenburg, where he remained for three years. Returning thence to England, he worked first under the celebrated John Ericson, at that time residing in England; next in one of Robert Stephenson's engineering offices; and lastly as a constructor under the engineer for the Huddersfield-Manchester Railway. In 1849 he left for Christiania and took, in the following year, the direction of the gasworks, in which position he remained till a month before his death in 1895. He has also taken part in the construction of waterworks and other engineering works in Norway, partly in collaboration with his younger brother, Carl Pihl, now one of the directors of the Norwegian railways.

Oluf Pihl's deep interest in the sciences was greatly stimulated during his stay in England. Amongst others he made here the acquaintance of Dr. Lee at Hartwell, in 1861 and 1862 President of the R.A.S. Some years after his returning to Christiania Pihl bought a small property, formerly the country house of the Norwegian poet Tullin (now long ago included in the town), and added to it a tower, in which he set up an equatorially mounted telescope of $3\frac{1}{2}$ inches aperture. With this he commenced a series of observations of the cluster Messier 34 (in *Perseus*), the results of which he published in 1869 under the title of *Micrometric Examination of Stellar Cluster in Perseus*, containing the results of the separate observations and a catalogue for 1865·0 of 85 stars between $2^h\ 31^m$ and $2^h\ 36^m$ in R.A. and $41°\ 56'$ to $42°\ 26'$ in declination.

Immediately after the completion of this series he took up a new and more extensive work, the observation of the following group of the great double cluster in *Perseus*. The resulting catalogue for 1870·0, containing 236 stars in R.A. $2^h\ 11^m$ to $2^h\ 16^m$ and Decl. $56°\ 11'$ to $56°\ 49'$, was not published till 1891 under the title *The Stellar Cluster* χ *Persei micrometrically surveyed.* In the preface the author says: "That so long a period as about twenty years has elapsed between the commencement and completion of the present work is owing, not so much to the limited time which I, as a business man, have had at my disposal for scientific occupation, as to the fact that during a long series of years,

and up to a comparatively short time ago, I was in very bad health, and therefore during many years almost, if not quite, cut off from all work in my observatory during the cold season, when that work which required most time had to be carried out."

A comparison with the results of previous observations of parts of the same cluster induced Pihl to make an investigation of a peculiar difference, evidently of physiological origin, between the results from occulting micrometers, which he had used in all his observations, and other micrometers. The investigation was given in the publication *On Occulting Micrometers and their Value as applied to exact Astronomical Measurements* (Christiania, 1893).

Among other mechanical contrivances with which Pihl occupied himself in his leisure hours was the construction of electrical clocks. His own house, as well as those of his three sons, was furnished with such, made by his own hands. The construction of the apparatus for giving the appulse to the pendulum had in early years led him to an investigation of magnetic attraction at short distances. Here he met with the problem of calculating, from the known fundamental law, the attraction between two parallel circles (surfaces or peripheries). As this leads to elliptical integrals, which, he could not master, he resolutely split up the areas or peripheries into small parts and made a direct calculation, partly by construction and interpolation. The results of these calculations, for several dimensions and distances, he has given in *Christiania Videnskabs-Selskabs Forhandlinger*, 1876 and 1881. The whole investigation, which included a very extensive series of experiments of different kinds, partly made with apparatus of his own construction, was published in 1878 in a book of 135 pages, *On Magnets*, forming an appendix to the proceedings of the said society.

Pihl was elected a fellow of the R.A.S. 1860 November 9, and has contributed some papers to vols. xxviii., xxix., and xxxiii. of the *Monthly Notices*, dealing partly with his observations of stellar clusters, partly with the meteoric showers of 1866 November 13–14 and 1872 November 27.

In 1850 he married a Swedish lady, Miss Tranchell, after whose death, in 1894, his own health rapidly declined. After suffering some time from Bright's disease he died 1895 July 1. His deep interest and extensive knowledge in science, his love of music, and his amiable hospitality will be remembered, not only among his countrymen, but certainly also among many foreign friends.

[The Council is indebted to Prof. H. Geelmuyden, of the Christiania Observatory, for the above notice.]

Alfred White was born in Holborn on 1811 March 3. He was the elder son of Paul Sleath White and grandson of William White (the first Grand Secretary of the English Freemasons and Secretary of the Honourable Artillery Company, Finsbury),

descended from the Whites of Cork, Ireland, and Dr. Paul Limrick, D.D., Rector of Scull, co. Cork, Ireland.

He was head of the firm of Alfred White & Sons, manufacturing chemists, of Castle Street, Saffron Hill, London, and West Drayton, Middlesex, which was established in 1775.

His residences were Horton Field, West Drayton, Middlesex, and Ashingdon Hall, Rochford, Essex.

Although he took great interest in astronomical research, his chief studies were archæology and chemistry.

He was Fellow of the Linnean Society, Fellow of the Society of Antiquaries, Fellow of the Chemical Society, &c.

He married (1845 November 6) Marianne, eldest daughter of the late Rev. Thomas Pugh, at Redbourne, near St. Albans, Herts (she died 1879 October 9). Issue, four sons and three daughters, all of whom are living except his eldest daughter, who died 1865 March 12.

He died at Horton Field, West Drayton, on 1895 March 8, being eighty-four years of age, and was buried in the family vault in Hillingdon Churchyard, Middlesex, with his wife and eldest daughter.

For the above particulars the Council is indebted to Mr. P. T. White, son of Mr. Alfred White. This death closes the list of Fellows of the Spitalfields Mathematical Society, who were elected Fellows of this Society in a body on 1845 June 13; and it is perhaps a fitting opportunity to reprint the account of the circumstances attending this election, as given in *Monthly Notices*, vol. vi. p. 256:—

"The President then announced that in pursuance of a resolution of the Council, which had been duly intimated to the Fellows, as required by the Bye-laws, the business of the Ordinary Meeting was now concluded, and that a Special General Meeting would immediately be held, to take into consideration a subject, of which due notice had been given to the Fellows by the following circular, which he requested the Secretary to read:—

"'Somerset House, June 5, 1845.

"'Sir,—I have the honour of notifying to you that in pursuance of a Resolution of the Council, passed on Friday, the 23rd of May last, a Special General Meeting of this Society will be held at the Society's apartments on Friday, the 13th day of June instant, immediately after the business of the Ordinary Meeting to be held on that day is concluded, for the purpose of taking into consideration and deciding upon a recommendation of the Council to suspend upon that occasion the Bye-laws relative to the Election of Fellows, and to elect as Fellows of this Society the remaining Members of the Mathematical Society (now reduced to nineteen in number, of whom three are already Fellows), without payment of the usual Admission Fees and

Annual Contributions (or compositions in lieu thereof), the Mathematical Society having announced its resolution to transfer its valuable Library, with its Records and Memorials, to the Royal Astronomical Society.

" 'I have the honour to be, Sir, your most obedient servant,

" 'ROBERT MAIN, Secretary.'

"It was then moved by Professor De Morgan, seconded by Mr. Galloway, and resolved unanimously:—

" 'That the recommendation of the Council in the circular now read be approved and adopted by this Meeting; and that on the Library, Records, and Memorials of the Mathematical Society being delivered over to this Society, the following sixteen gentlemen, Members of the Mathematical Society, be admitted Fellows of the Royal Astronomical Society without payment of the admission fees or annual contributions required by the Bye-laws—viz.:

William Wilson, Esq.	Thomas K. White, Esq.
Robert Graham, Esq.	Philip James Chabot, Esq.
Robert Porrett, Esq.	Charles O. Dayman, Esq.
James Scott Bowerbank, Esq.	Thomas Cooper, Esq.
Julius Page, Esq.	John Walton, Esq.
John Williams, Esq.	Jacob Hoyer, Esq.
Henry De Berckem, Esq.	Robert Arthur Graham, Esq.
Alfred White, Esq.	Thomas Taylor, Esq.

and that the remaining three members of the Mathematical Society—viz.:

Benjamin Gompertz, Esq.	John Lee, Esq.
John James Downes, Esq.	

or such of them as are liable to the payment of Annual Contributions, be exempted in future from such liability.' "

At the meeting of 1845 November 14 "Mr. Stratford stated that the books received consisted of

76	volumes	folio
622	„	4to
1,442	„	8vo
311	„	12mo

131 books not bound or catalogued, and that six volumes were yet to be delivered; that the Council had this day determined to complete the deficient sets of the most valuable works, to re-arrange the library, and to prepare a new catalogue, uniting the books of the two societies as early as possible."

PROFESSOR DR. FRIEDRICH WILHELM GUSTAV SPÖRER was the son of a merchant of Berlin, in which city he was born on

1822 October 23. He was educated at the Friedrich Wilhelm Gymnasium and at the University of Berlin. Here he studied under Steiner, Ohm, Minding, Poggendorf, Mitscherlich, and other professors, but those who exercised the greatest influence upon him were Encke and Dove. He took his degree in Mathematics and Astronomy in 1843, and obtained his doctorate for a thesis entitled "De Cometa qui anno 1723 apparuit." In 1844 he served as a computer under Encke at the Berlin Observatory, and he computed the perturbations of Encke's comet for the period 1838 to 1845; later he derived the elements of the comet from the apparitions of 1819–1838, and computed its ephemeris for a part of the year 1845. This first contribution to astronomy appeared in the *Astronomische Nachrichten*, and was incorporated in a paper on that comet by Encke himself. From 1846 until 1874 he adopted the profession of teaching. He first went to the Gymnasium at Bromberg, as instructor in mathematics and natural science; in 1847 to Prenzlau; and in 1849 to the Grammar School at Anclam, where he occupied a post for twenty-five years and was eventually elected pro-rector. But though engaged in other occupations he did not lose his strong early love for astronomy, and by the year 1860 it led him to devote his leisure hours to that systematic study of Sun-spots which has made his reputation as an astronomer. Though at first provided with but a small and indifferent telescope, furnished only with a ring micrometer, he quickly brought out his first results; the earliest of the long series of solar observations which he communicated to the *Astronomische Nachrichten* appearing in No. 1315, with date 1861 June 13, and bearing the title "Beobachtungen von Sonnenflecken und daraus abgeleitete Elemente der Rotation der Sonne." In this paper he gives the rotation period of the Sun as deduced from the observation of a number of spots, which appeared to him to be of a stable character. Having found the inclination of the Sun's equator to the ecliptic to be approximately $7° 30'$, and the longitude of the ascending note to be $78°$, he computed the heliographic coordinates for a considerable number of single spots, and from each series the angle of rotation of the Sun (ξ) and its time of rotation (T) were deduced. The means of these values were $\xi = 14°{\cdot}2965$ and $T = 25^d\ 4^h\ 21^m$. This paper and the similar communications which followed it brought him under the notice of many men of distinction and influence, amongst others of Professor Schellbach, the tutor to the Crown Prince Frederick William (afterwards the Emperor Frederick). In recognition of the good work that he had done the Crown Prince gave him in 1868 a good 5-inch glass equatorially mounted and driven by clockwork. In the same year he went to the East Indies with Professor Tietjen and Dr. Engelmann to observe the total solar eclipse at Mulwar, in the Bombay Presidency, in longitude $5^h\ 3^m\ 21^s$ east, and north latitude $16° 34'{\cdot}7$, but clouds prevented the observation of totality. This was the only interruption of a considerable length of time

that his Anclam observations experienced. Six years later he accepted an official position in the Astrophysical Observatory at Potsdam, and was promoted to the rank of "Chief Observer" in 1882. His researches during these latter years (1871–1893) are contained in the Publications of the Astrophysical Observatory, and his concluding observations appeared in the first half of the tenth volume, issued very shortly before he died. Professor Vogel's farewell to his chief observer and colleague in the Introduction came, therefore, pathetically soon before his death. The director says that with the "first part of this publication Professor Spörer closes the long list of his works on Sun-spots. The results of his labours given in the Publications of the Astrophysical Observatory embrace a period of over twenty-two years, from 1871 October 1 to 1893 December 31, and constitute an eloquent testimonial to the untiring industry and the great sense of duty of the renowned observer, who leaves the ranks of my colleagues on 1894 October 1, and enters into a well-earned rest." That rest he did not long enjoy, for he passed away at Giessen, on 1895 July 7, while on a visit to his children, without having sustained any weakening of his mental or physical powers or any previous indication of the disease which caused his death—paralysis of the heart. Professor Spörer left three sons and four daughters. One daughter was married to Professor Müller, Observer at the Observatory of Potsdam, and author of several astronomical works.

His colleague, Dr. O. Lohse, sums up his character in the following terms:—

"Spörer was a genuine Berliner of equable and cheerful temper; he bore all the vicissitudes of life with undisturbed equanimity, and always at once reverted to his daily routine, *i.e.* to his study of the Sun, now so beloved by him. His constancy in this occupation as well as his conscientious discharge of his official duties was worthy of all admiration."

Amongst the recognitions which his long-continued labours received from foreign nations may be mentioned his election as Corresponding Associate of the Società degli Spettroscopisti Italiani on 1889 February 10, and the award to him on 1885 December 14 of the Valz Prize of the Institute of France.

The chief results of Spörer's labours in the field which he made so thoroughly his own were the redetermination of the mean rotation period of the Sun, resulting in a slightly different value from that found by Carrington—$25^{\cdot}445$ days as against $25^{\cdot}38$ for latitude 15°—the confirmation of Carrington's observation of the decrease of the angular velocity of Sun-spots, with their distance from the equator; the determination of the amount of this drift, and its representation by a simple empirical formula—$\xi = 8^{\circ}{\cdot}548 + 5^{\circ}{\cdot}798 \cos$ (lat.)—the determination of the length of the Sun-spot cycle from observations extending over 38 years; and the demonstration that the progress of the cycle not only involves

a change in the numbers and areas of the spots, but also in the zones which they affect; so that at the beginning of a new cycle the spots are found chiefly in high latitudes, but as the cycle progresses ever in lower latitudes, until at length the equator is reached. A feature of this "law of zones," which he pointed out, is the associated fact that the actual Sun-spot cycles overlap, the new current having its beginning before the expiring one has run out to its close. Besides his own observation of Sun-spots, Professor Spörer was indefatigable in searching out early records, and in two papers entitled, "Ueber die Periodicität der Sonnenflecken seit dem Jahre 1618," and "Sur les Différences que présentent l'Hémisphère nord, et l'Hémisphère sud du Soleil," communicated respectively to the Royal Leopold-Caroline Academy and to the *Bulletin Astronomique*, he traced back his "law of zones" to the year 1619, and showed that although there is on the whole an even balance between the number of spots in the two hemispheres, yet in three periods of the Sun's history the southern spots have predominated. A third and most interesting fact brought out in these papers was that of the apparent suspension of both the law of the spot cycle and the "law of zones" for about 70 years at the end of the seventeenth century. Dr. Spörer's regular observations of Sun-spots from his rotation No. 1 in 1861 January to rotation 445 in 1894 January are published in six volumes. The first two, or the Anclam observations, were issued as the thirteenth volume and its appendix of the publications of the *Astronomische Gesellschaft* in 1874 and 1876. The remaining four are contained in the *Publications of the Astrophysical Observatory of Potsdam* as vol. i., No. 1; vol. ii., No. 5; vol. iv., No. 17; and vol. x., No. 32. These volumes are illustrated by charts showing, rotation by rotation, the arrangement of the spots in longitude and latitude, in a somewhat similar form to that adopted by Carrington.

Professor Spörer was elected an Associate of the Royal Astronomical Society on 1886 November 12.

Friedrich Tietjen was born on 1832 October 15 at Garnhold, a village of Westerstede parish, in the Duchy of Oldenburg. His father owned a small farm, and Friedrich, on the early death of his elder brother, remained the eldest of six children and heir to the property. He was educated at first in a volksschule, and here showed great inclination and aptitude for figures; but this fact had little interest for his father, who was chiefly concerned that his son should be a good farmer, and to that end required him, even before he left school at the age of fifteen, to work in farm and field like other boys. Mathematics had, however, a special attraction for him, and he taught himself from such books as he could borrow, though his studies could only be pursued at night after a hard day's work, and if not perhaps unknown to, at any rate much against the will of, his father. It was contrary to all traditions of the family that the eldest son should resign

his birthright, but the father determined that the farm should at least be handed over to a sturdy farmer, and not to a student. This was a trying time for the young man, who could with difficulty conceal his own inclinations. A chance of escape suggested itself in his military service, for he hoped to get to Oldenburg, and there find opportunity for further education. But he was rejected from physical weakness, and his grief and despair were so great that his father, who had hitherto refused to listen to the advice of his old friends, at last realised that his son would never make a farmer. He accordingly yielded to his son's wishes, on the condition that he resigned his birthright. Tietjen forthwith went to the high school at Oldenburg, and found in Professor Harms an exceptionally able instructor in those mathematical studies which he loved. Thence he proceeded to the Collegium Carolinum in Brunswick, where his diligence and ability were so manifest that in 1859 he entered the University, though at the advanced age of twenty-seven.

Next he went to Göttingen, and a year later to Berlin; and here it was that his love for astronomy was awakened. He began in 1861 to busy himself with observations and reductions of small planets and comets, and in 1862 was appointed by Professor Encke second assistant in the Observatory, with charge of the great refractor and magnetic observations. In 1865 Professor Foerster succeeded to the directorship of the Observatory, and Tietjen became first assistant, in which position he remained until 1874, when he was appointed Editor of the *Berlin Jahrbuch* and Director of the new Rechen-Institut, founded in connection with the Observatory. With Professor Foerster he undertook the management of a school of instruction in scientific computations; and in 1878 succeeded Professor Bremiker as Editor of the *Nautisches Jahrbuch*.

Tietjen worked very hard during his thirteen years as assistant at the Observatory, especially at observations of small planets, to which the *Berlin Jahrbuch* pays special attention. The situation of the Observatory in the midst of the city made such work very difficult and laborious. In 1866 he had the good fortune to find one planet—*Semele*—himself, in watching the recently discovered *Io*. From the year 1869 he did a large amount of work in observing comparison stars with the large transit circle. The accounts of his work of this kind, as well as of his magnetic observations at Berlin, in the *Astronomische Nachrichten* and the publications of the Observatory, testify to their great value.

Some other matters claimed his attention. In the course of the Mid-European Survey it was resolved to fix the astronomical position of some point in Oldenburg, and the selection fell on Dangast, the position of which was determined by Tietjen in the summers of 1866 and 1867, with the help of Professor Albrecht for the longitude work. In 1868 Tietjen spent some time in Gotha, working at perturbations under Hansen's superintendence; and

undertook some calculations for a new theory of *Jupiter*, which were, however, interrupted by the expedition to observe the Total Solar Eclipse of 1868 August 18. Two expeditions were sent—to Arabia and to India—by the Prussian Government.

He also undertook spectroscopic observations on several occasions. In 1868–9 he made an unsuccessful series of attempts to see protuberances without a spectroscope by absorption of the general light of the Sun. In 1872, at nearly the same time as Respighi, he found that the strongest line in the spectrum of the zodiacal light can be seen in all parts of the sky. And, finally, in 1873 he measured the hydrocarbon bands in the spectrum of Encke's Comet with a spectroscope designed for the purpose.

From 1874, when Tietjen undertook the editorship of the *Berliner Jahrbuch* (first jointly with Foerster, later alone) and the directorship of the Rechen-Institut, he practically ceased observing, and turned his attention to theory and computation. He was a ready and most accurate computer, and undertook many investigations of his own, in addition to the heavy regular work. The *Jahrbuch* under his editorship kept pace with the advances of knowledge; and several appendices contain personal contributions of great value, chiefly relating to the determinations of planetary orbits and improvements in the methods of reduction.

Tietjen was an indefatigable worker. He had a wonderful faculty for solving instrumental and mechanical problems, of great use in the Observatory work. The number of his publications would have been greater could he have found opportunity to carry out all his ideas. Against his undoubted faculty for arranging them, and condensing them into scientific results, must be set a certain natural disregard of form, perhaps due to his exceptional early life and late development, which he could never shake off, and which appeared also in his private life. A somewhat rough exterior hid, however, a heart of gold. By his colleagues, friends, pupils, and by his countrymen of all ranks, was he beloved and respected, and the simplicity and uprightness of his character will long live in their memory.

He was of sound constitution, and though he did not spare himself, never ill. About the end of the eighties he began to suffer from shortness of breath, which gradually developed and, complicated by heart-disease, made his last years sad and painful. Visits to baths and a winter in Italy (1894–5) only brought temporary relief, and on 1895 June 21 he died.

Tietjen was elected an Associate of our Society on 1881 June 10, together with Gyldén, E. C. Pickering, Tempel, and Tisserand. His name occurs four times in the index to volumes i. to xxix. of the *Monthly Notices*, and twice in the index just published, as contributing elements of minor planets, but these elements were always copied from the *Astronomische Nachrichten*.

[For the above particulars of his life and work the Council is indebted to his close personal friend Dr. H. Romberg, of Berlin.]

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

With the transit-circle 12467 observations of transits and 12445 of meridian zenith distances were made in 1895, giving an average, excluding Sundays, of about 40 per night. About 3000 observations were made in the two months of August and September. The total number of stars observed during the year is 2633.

The Moon was observed 137 times with the transit-circle; the mean error in R.A. of Hansen's Lunar Tables with Newcomb's Corrections deduced from these observations is $-0^s{\cdot}065$. The errors for the years 1883–95 are as follows :—

	s		s		s
1883	+0·032	1888	+0·079	1893	+0·036
1884	+0·021	1889	+0·010	1894	−0·019
1885	+0·028	1890	+0·020	1895	−0·065
1886	+0·029	1891	+0·079		
1887	+0·068	1892	+0·069		

The number of observations of pairs of reflexion and direct observations of stars in zenith distance was 642. The apparent correction to the Nadir observations deduced from these varies from $+0''{\cdot}03$ to $-0''{\cdot}50$ in the several months of the year. The mean for the year is $-0''{\cdot}26$, agreeing with the results of the three previous years. For the years 1890 to 1894 the corrections are $+0''{\cdot}08$, $+0''{\cdot}07$, $-0''{\cdot}25$, $-0''{\cdot}34$, $-0''{\cdot}27$.

The series of observations begun in 1894 December, in which pairs of stars of nearly the same N.P.D., and at an interval of 5 or 10 minutes in R.A., are observed in zenith distance, the one directly and the other by reflexion, alternately on alternate nights, was continued during the year. Altogether 320 observations have been made up to the end of 1895, giving 160 determinations of the R−D discordance.

The personal equation machine has been used to determine personality in observations of the first and second limbs of the Sun or Moon. Altogether 24 determinations of the personality of six observers have been made during the year.

The Moon has been observed with the altazimuth in the first and last quarters as in previous years, 66 observations being made in the year. The building of the new altazimuth pavilion was completed, and the dome erected in the autumn. The heavier portions of the new altazimuth were placed on the pier on May 6, and the instrument is now being mounted. A working catalogue of fundamental stars for the azimuths in which the instrument will be used has been prepared, as well as various tables required in the reductions.

Two comets were observed during the year with the Sheepshanks equatorial: Encke's comet on eight nights, and Comet (*d*) 1895 on one night; Comet (*c*) 1895 (Perrine) was observed with the altazimuth on two nights.

Forty-eight occultations of stars by the Moon were observed during the year, 21 of these, of which altogether 139 observations were made by 11 observers, occurring during the total lunar eclipse of 1895 March 10. Thirty-two phenomena of *Jupiter's* satellites were observed with the altazimuth or one of the equatorials.

With the 28-inch refractor 277 sets of micrometric observations of 153 double stars have been made, all the measures of a star on one night (usually 4 of distance and 3 of position-angle) being counted as one set. In 92 stars the distance between the components was under $1''\cdot5$, and in 30 of these under $0''\cdot5$. A good series of measures of κ *Pegasi*, a pair which is closing rapidly, has been obtained, the last measures being made on November 18, when the distance apart was less than $0''\cdot1$. Measures of the diameters of *Jupiter* and his satellites begun in 1894 were continued on 19 nights. Altogether 263 measures were made of *Jupiter's* equatorial diameter, 216 of the polar diameter, and about 50 measures of the equatorial and polar diameters of each of the satellites. In addition to these 100 measures of *Jupiter's* equatorial diameter were made with the double-image micrometer. About 800 measures of the diameters of *Saturn* and his rings and of the diameter of *Titan* were made on 14 nights with the filar micrometer. The measures of *Jupiter* and *Saturn* have been published in the *Monthly Notices*, and the measures of double stars will be communicated to the Society shortly.

With the half-prism spectroscope 284 measures have been made of the displacement of the F line in the spectra of 29 stars, and 15 measures of the *b* line in the spectra of 4 stars; 38 measures of the displacement of these lines in the spectrum of the Moon have also been made as a check on the adjustments. A few experiments have also been made in photographing stellar spectra.

A considerable improvement in the conditions of observing with the 28-inch equatorial has been effected by the use of canvas sails to act as wind screens on the two sides of the shutter opening of the 36-feet dome. These sails, which were completed at the end of February, are each 22 feet high by 8 feet wide, and can be hauled up and down easily by peculiar tackle specially suited to the conditions of the case.

The photographic telescope of 26 inches diameter presented by Sir Henry Thompson is being constructed by Sir H. Grubb, and will, it is hoped, be ready very shortly for inspection at his works. The crown disc for the 26-inch object-glass was supplied last March, the flint having been delivered in the previous August.

With the Astrographic Equatorial (which was not in use till February 25, during the repair of the shutter, which was blown off the dome during the gale on 1894 December 22) 547 plates with 1,382 exposures were taken in the year 1895 on 120 nights; and of these 138 have been rejected—viz. 53, as not coming up to the standard in showing faint stars; 41, from the *réseau* not being printed sufficiently clearly; and 44 on account of partial fogging, wrong setting, faulty development, or mechanical injury. Of the 409 successful plates, 82 are for the Chart, 263 for the Catalogue, 45 are Standard Areas, 10 for the adjustments of the instrument, 5 are photographs of other regions, and 4 were taken with the enlarger (enlargement six times). When practicable a trail has been taken each night on a catalogue plate, and 72 plates with trails have been secured.

Each plate has undergone a preliminary examination to see whether it was generally satisfactory, and whether the limits of magnitude were approximately reached as inferred from the 20^s exposure, which should give 9th magnitude stars of Argelander's scale. When the measurement of the Catalogue plates was begun, it was found that many photographs which had been previously passed were not suitable for measurement with the glass-scale micrometer. A revision of the plates previously passed has been made, and such as were not considered suitable for measurement have been rejected.

The following table shows the progress made in the photographic mapping of the heavens up to the end of 1895:—

Zones Decl.	No. of Fields Required.	No. of Fields Photographed For Catalogue.	For Chart.
65°–69°	376	354	224
70–75	360	255	184
76–80	216	76	71
81–90	197	0	0
Total ...	1149	685	479

Measurement of the plates for the Catalogue is being systematically carried on with the duplex micrometer mentioned

in the last Report. Both the 6^m and 3^m images are measured and the means taken. During the year 493 quarter plates have been measured, which, with 16 quarter plates measured at the end of 1894, gives 509 quarter plates, equivalent to 127 plates, as the total number measured. The rate of measurement has been increased to about 180 plates a year since October.

The stars in the following portions of the sky have already been measured on each of two plates:—

Decl. 65°–66°	R.A. $11^h\ 15^m - 0^h\ 36^m$	
66–67	11 24 – 0 0	
67–68	11 30 – 0 0	(Except $22^h\ 10^m - 22^h\ 30^m$)
68–69	19 0 –20 0	

On the 496 quarter plates, which cover these portions of the sky, the images of 17,250 stars have been measured, and of these 13,250 have been measured on each of two plates. The number of stars per plate varies greatly in different parts of the sky. The largest number on any plate completely measured as yet is 664 on the plate whose centre is at R.A. $21^h\ 54^m$ Decl. $+66°$; and the smallest is 67, on the plate whose centre is at R.A. $2^h\ 42^m$ Decl. $+66°$.

Towards the determination of the Right Ascensions and Declinations of the stars the following steps have been taken. From the Right Ascensions and Declinations given in the catalogues of the *Astronomische Gesellschaft*, "Standard Co-ordinates" have been deduced for all stars on 72 plates which are contained in these catalogues. By a comparison of these with the measured co-ordinates, plate-constants have been determined, from which the "Standard Co-ordinates" of other stars on the plates may be obtained by means of a linear correction, and the Right Ascensions and Declinations deduced by a trigonometrical transformation, if desired. A full account of this, as well as of the comparison of 30 overlapping plates, is given in the *Monthly Notices*, 1896 January.

Some experiments have been made in the reproduction of the Chart plates, so as to form a map of the portion of the sky from R.A. $19^h\ 0^m$ to $20^h\ 50^m$, and Decl. 64° to 71°. Positives on glass of the 37 negatives covering this region have been taken, and from these platinotype, gelatino-chloride, and bromide card-prints have been made for comparison. From a preliminary examination of these, it seems that the bromide cards are the most suitable, and that on these very few, if any, stars are lost, which is far from being the case with the platinotype prints. The bromide cards have the advantage of not needing to be mounted and rolled, and are very convenient for use.

The Dallmeyer photoheliograph, of 4 inches aperture, now mounted on the terrace roof of the south wing of the new building in the south ground, has been the only instrument employed

for solar photography in 1895, the Thompson photoheliograph not being at present available, in consequence of the progress of the building operations, in the course of which the Lassell equatorial and dome have been dismounted. With the Dallmeyer instrument photographs of the Sun were obtained on 234 days, and of these 482 have been selected for preservation, including 13 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1895 November 5, and from Mauritius up to 1895 July 25, leaving only one day—1895 January 7—for which no photograph is yet available for measurement in the year ending with the date of the last Mauritius negative received.

The Greenwich photographs have been measured in duplicate up to the end of 1895, and the areas and heliographic positions of the spots and faculæ have been computed. The complete results for 1893 have been printed, and the daily results for 1894 have been passed for press up to April 26; the manuscript has been sent to the printer up to May 30, and that for the rest of the year is nearly ready. The measurements and reductions for 1894 proved distinctly heavier than for 1893, although there was a falling off in the mean daily spotted area. This was owing to the number of small groups, and to the great complexity of some of the larger groups. The decline in the spotted area has continued through 1895, and has brought about a slight diminution in the work of measurement and reduction; the number of volumes of the forms used in the computation of the areas and heliographic positions of the spots being fewer in 1895 by about one-fifth than in 1894, and by about one-tenth than in 1893. The work, therefore, is still very heavy, for on no occasion in 1895 was the Sun free from spots.

The publication of the final results of the Greenwich-Montreal longitude determination has been delayed, owing to the pressure of other work, and the inadequacy of the existing permanent staff.

The transit observations at contiguous stations in the front court, to determine the difference of longitude between them were continued on four nights with the instruments used in the Paris-Greenwich longitude determinations. The observations have not yet been reduced.

Observations were made on the pier of the Transit Pavilion by Captain Burrard, R.E., and Captain Conyngham, R.E., to determine the difference of longitude of Greenwich and Potsdam, in connection with the re-determination of the longitude of Madras. From June 14 to July 1 Captain Burrard was at Greenwich and Captain Conyngham at Potsdam; they interchanged stations July 11–25, and determined their personal equations at Greenwich May 28–30, and at Potsdam July 30–August 3.

The volume of *Greenwich Observations* for 1893 is printed, with the exception of the Introduction, of which proofs have

been received. The printing of the volume for 1894 is advancing.

Electric lighting was introduced throughout the Observatory, with the exception of the Magnetic Observatory and the new Physical Observatory, last June, and has also been applied successfully to the principal instruments, including the Transit Circle. It is thoroughly satisfactory and economical.

The building of the north wing and completion of the central octagon of the new Physical Observatory, on which the Thompson 26-inch photo-telescope will be erected, was begun in 1894 September. Delays occurred from the severe frost of last spring, and later from failure in the supply of terra-cotta, and the building is not yet quite finished. Meanwhile the Lassell Dome was dismounted by Messrs. Cooke, so that its re-erection can be begun as soon as the building is ready. The Merz Refractor (12·8-inch), which was mounted on the Lassell Equatorial, will be used as a guiding telescope on the Thompson photographic telescope.

There have been no changes in the permanent staff during the year, and the two vacancies among the second-class assistants have not yet been filled up, a scheme for reorganisation of the staff being still under the consideration of the Government.

The Observatory will shortly lose the services of Mr. Criswick, who retires on pension on January 31, after a useful and honourable service of forty-one years at the Observatory.

Royal Observatory, Edinburgh.

During the year 1895 great progress has been made towards the completion of the new Royal Observatory at Blackford Hill. The dwelling-houses have been occupied for several months, and the boundary wall is now nearly finished. The Dunecht 15-inch refractor by Grubb was mounted in the east dome in July and August, and finally adjusted in September, since which time it has been regularly employed in observations of comets, and occasionally of minor planets, but the work has been much interrupted by unfavourable weather.

The sidereal clock by Frodsham formerly at Dunecht has been mounted in a specially prepared clock chamber, together with the standard sidereal clock by Dent, presented in 1855 to the Calton Hill Observatory by Sir Thomas Makdougall Brisbane. The Brisbane clock has been fitted in a cast-iron air-tight case, in which a constant barometric pressure of twenty-five inches is maintained. The clock chamber is in the base of the pier of the large east dome. It is lined with silicate cotton, and is provided with two double doors packed with the same non-conducting material, so that the temperature in the chamber remains nearly constant during long periods. These two clocks are connected with a small chronograph by Fuess, which is mounted

in the chronograph room, under the west dome, and also with a sounder in the experimenting room, by means of which the comparisons with the mean-time clock by Molyneux are made. The Fuess chronograph is provided with two signal levers, so that observations made at any two different instruments can be recorded simultaneously. The large four-barrel chronograph by T. Cooke & Sons is in process of being mounted.

The time service, which includes the working of the time ball on the Nelson Monument, the firing of the time guns at Edinburgh Castle and at Dundee, and the controlling of clocks throughout the city of Edinburgh, was transferred from the old Observatory to Blackford Hill on November 8, and has since been carried on without interruption, the time observations being made with the fine 4-inch reversing transit by T. Cooke & Sons, and the time distributed by the Molyneux clock.

Observations for the determination of the difference of longitude between the old and new Observatories were made by Mr. Heath and Mr. Ramsay on seven nights in the autumn with the 6·4-inch transit instrument at Calton Hill and the reversing transit at Blackford Hill. As at that time there was no telegraphic communication between the two stations, two mean-time chronometers were each night carried to and fro between the Observatories, two journeys being usually made each way. In order to eliminate personal equation, the observers changed stations when about half the observations had been made. The result places Blackford Hill $1^s \cdot 17$ west of Calton Hill, with a probable error of $\pm 0^s \cdot 05$. The adopted longitude of the transit house at Blackford Hill is $12^m \ 44^s \cdot 2$ west of Greenwich, and of the 15-inch refractor $12^m \ 44^s \cdot 0$.

The workshop, with its lathes and other apparatus, and the large photographic rooms have been in use for some months. The barograph and barometer, the thermometers and rain gauges, were all mounted in good time to begin a continuous meteorological record on 1896 January 1. A monthly return will be made to the Scottish Meteorological Society.

Although work at the old Observatory was given up in November, the rain-gauge record there was continued to the end of the year, when it was taken up by the city authorities, by whom it is now being carried on. The old Observatory has been acquired by the city, the transit instrument, mural circle, and vertical circle having been left there on loan, with the sanction of her Majesty's Government. The weekly readings of the rock thermometers there will however be continued, as before, by one of the Royal Observatory staff. The regular daily readings of the bifilar pendulum at Calton Hill were carried on by Mr. Heath until October 28, when the instrument was removed to Blackford Hill, where it will be remounted along with a similar pendulum vibrating at right angles to it, the pair being arranged to give a continuous photographic record. On June 9 a curious instance of sudden oscillation of the pendulum was observed, and a short

account of it was published in *Nature* of July 4. The total oscillation in the plane of the meridian was $0''\cdot4$ of arc to the north and $0''\cdot5$ to the south.

The reduction of the observations made by Mr. Heath for the re-determination of the latitude of Calton Hill has been completed. The arithmetic mean of 218 observations gives

$$\phi = +55^\circ\ 57'\ 23''\cdot19 \pm 0''\cdot04,$$

in exact agreement with Henderson's determination made with the same instrument sixty years ago. Dr. Chandler's reduction to mean latitude was computed from the equation given in the *Astronomical Journal*, vol. xiv. p. 74, but did not sensibly affect the above result or its probable error. It does not appear, therefore, that the observations with the Mural Circle are of sufficient accuracy to show the small periodic changes of the latitude.

The 24-inch Grubb reflector from Calton Hill is in process of erection in the west dome at Blackford Hill, and will shortly be ready for use. The driving clock is being provided by Messrs. Ritchie & Son, of Edinburgh, with maintaining power and electric control. The Transit House is now ready for the Dunecht 8·6-inch Transit Circle, which is still in the hands of Mr. Simms, who has retouched the object glass and made some improvements in the illumination, &c.

Mr. Ramsay has been engaged during nearly the whole of the year in the arrangement and fitting up of the new Observatory, and in mounting the instruments and clocks. He has now practically completed the extensive system of electric wires for the sympathetic clocks and chronographs, by means of which observations made with any of the instruments in the Observatory can be recorded on either of the chronographs. Mr. Ramsay has also, to a large extent, conducted the business correspondence of the Observatory.

In September Dr. J. Halm joined the staff of the Observatory, and has since been in charge of the 15-inch refractor, with which the following observations of comets have been secured: Comet Swift four times, Perrine once, and Brooks nine times. He has also given much time to arranging the books of the Crawford Library, which are now completely accessible, while considerable progress has been made with the books from Calton Hill. Dr. Halm has made some observations with the reversing transit in the prime vertical for the latitude of Blackford Hill, the result being in close agreement with the value $+55^\circ\ 55'\ 28''\cdot0$, found by Dr. Becker, which may be safely retained as the provisional latitude of the Observatory.

In spite of the varied work in hand the reduction of the Henderson observations has not been lost sight of, and has made steady progress in the hands of Mr. Heath.

During the year six circulars have been issued, referring to the comets above mentioned. To these circulars valuable contributions have again been made by Mr. A. Berberich, of Berlin.

Royal Observatory, Cape of Good Hope.

Mr. J. Power has been appointed junior assistant *vice* Mr. W. H. Cox, promoted.

The chief feature of the work of the Observatory during 1895, following the policy indicated in last report, has been the progress made in overtaking arrears of reduction and publication.

The Cape General Catalogue for 1885, with its appendices, and the annual results of meridian observations for 1885, 1886, and 1887, have been printed, and during the year have been placed in the hands of astronomers. The annual results of meridian observations for 1888, 1889, 1890, and 1891 have been passed through the press. The manuscripts of the annual results for 1892, 1893, and 1894 are in the hands of the printer, and some of the sheets have been passed for press.

The printing in two volumes of *A Determination of the Solar Parallax and the Mass of the Moon from Observations of Iris, Victoria, and Sappho*, is approaching completion. The part of the work referring to the meridian observations of the comparison stars is by Professor Auwers, that of the discussion of the heliometer observations of *Iris* by Dr. Elkin.

The first volume of the Cape Photographic Durchmusterung, containing the places of 152,000 stars, derived by Professor J. C. Kapteyn from the Cape photographs, between the limits of Declination $-19°$ and $-37°$ (both inclusive), has been passed through the press. The introduction is in the press. The manuscript of vol. ii. of the same work, containing the places of 158,000 stars between the limits of Declination $-38°$ and $-52°$ (both inclusive), is ready for press.

A complete account of the Geodetic Survey of South Africa has been passed through the press, with the exception of the index and general map, which are still in the printer's hands, besides an account of the new Geodetic Survey executed by Colonel Morris, R.E., under the direction of H.M. Astronomer. The whole includes a complete re-reduction of Sir Thomas Maclear's triangulation and a comparison of the astronomical results with the geodetic latitudes, longitudes, and azimuths, computed both with Clarke's and Airy's elements of the Earth. The work has been printed at the Cape for presentation to the Cape Parliament at its next session, and will afterwards be distributed.

The current reductions of meridian observations are advanced as follows :—

The computations	of	Mean R.A.	are complete to	1895 Sept. 3
„	„	„ N.P.D.	„ „	Nov. 22
„	„	Apparent R.A.	„ „	Sept. 3
„	„	„ N.P.D.	„ „	Dec. 31
„	„	R.A. corrected for collimation and level only	are complete to ...	Dec. 1

Note.—The reductions in R.A. after September 3 were necessarily delayed until the double transits of circumpolar stars observed during the winter months had been discussed, and definitive places formed for determining the azimuth in those seasons when double transits could not be obtained.

The Cape Ten-year Catalogue for the Equinox 1890 is well advanced, and will contain the results of all meridian observations of stars made since 1885 August 24 till the end of 1895, reduced to the Equinox 1890, excepting the circumpolar stars, fundamentally observed in 1895, which will be given in an appendix reduced to the Equinox 1895. All observations to the end of 1894 have been reduced to the common Equinox 1890, and the means have been taken. The corrections for flexure, change of latitude, &c., have still to be made, the mean latitude, refraction, &c., to be discussed, and the corresponding corrections applied.

With the special provision made for the reduction of Sir Thomas Maclear's observations, 1861–70—

The Apparent Right Ascensions have been examined to 1864 December 31;

The Apparent N.P.D.'s have been examined to 1867 August 13.

The star-corrections for 1861–1866 and for 1868 are computed. The tabular places of the Moon corresponding to the instants of transit have been computed for the years 1862, 1863, and 1864.

The observations made with the zenith telescope for aberration and change of latitude are completely reduced to mean difference of zenith distance (north—south), and corrected for screw-error, &c. The results are being finally revised previous to discussion.

With the heavy pressure of other arrear work the heliometer observations for stellar parallax, the heliometer and photographic observations of *Jupiter's* satellites remain unreduced. The occultations observed since 1881 have been partly reduced, and the work will be completed as soon as circumstances permit.

The progress made in overtaking arrears of publication and reduction has been purchased at the severe price of limiting the observing activity of the staff, a policy which H.M. Astronomer has followed with great reluctance, but which was the only alternative one to that of increasing, instead of diminishing, the already large stock of unreduced and undiscussed observations. Mr. Power's appointment to fill a position in the staff which had practically been vacant since 1892 April, has, to a certain extent, relieved the pressure. But in view of past experience and the necessity of making provision for efficient working of the McClean telescope, it is obvious that a substantial increase in the Observatory staff is essential.

During the year 1894 nearly the whole of the observations

for the Cape Ten-year Catalogue for 1890 were completed. It remained to make a series of fundamental observations of circumpolar stars to form an appendix to the Catalogue similar to that attached to the Cape General Catalogue for 1885; the instrument accordingly has been almost exclusively devoted to this work.

These observations naturally occupy much longer time than observations of quicker moving stars, hence a comparatively small number of observations was obtained.

With the transit-circle there have been made:

Number of transits observed	2872
Number of declinations	2240
Determinations of collimation	94
" level	276
" azimuth	437
" run	247
" nadir	248
" flexure	48

The following occultations of stars by the Moon were observed:—

Disappearance at the dark limb	8
Reappearances	5
No. of separate phenomena	13

With the zenith telescope: Investigations of the errors of the screw and values of levels and screw have been made in connection with the series of observations for aberration and change of latitude.

There were no comets favourably situated for observation from this Observatory.

Comet *Brooks* was searched for but not found, as no motion was given in the cable message, and attention was chiefly given to sweeping *south* of the position given; but the comet was moving rapidly to the north. The 6-inch equatorial, which alone has an eyepiece of large field, was dismantled at the time, its dome being under repair.

Comet *Perrine* was seen once only, viz. on the morning of December 13, near the eastern horizon, the star *Antares* being visible in the same field. The image of the comet faded in the advancing daylight before the definition was sufficiently steady to permit observations to be made. The image of the star remained bright and observable after that of the comet had become invisible. All attempts to detect the comet near perihelion in daylight were unsuccessful. After perihelion the comet could be seen from Sea Point after sunset, but was hid from the

Observatory by Table Mountain, which cuts off about 8° from the horizon in that azimuth.

With the photographic telescope the following work has been accomplished :—

	No. of Plates Exposed.	Exposures No.	Duration.
Catalogue plates	91	273	6^m, 3^m, 20^s each
Chart plates	367	367	(up to) 60^m
Kapteyn-Pritchard areas ...	61	183	6^m, 3^m, 20^s
Circumpolar plates for Professor Jacoby	16	48	6^m, 3^m, 20^s
Speed, trial and adjustments	14	28	
Plates for light curve of R Velorum...	18	129	6^m
Stars suspected of variability in Kapteyn's discussion of the Cape Photographic Durchmusterung	57*	144	6^m

Of the 367 chart plates exposed, only 240 have been passed as successful. The failures have arisen in part from interruptions by cloud and by bad definition, but chiefly because two successive supplies of plates turned out to be faulty; so that, though the rejected negatives would be available for purposes of measurement, they are unfit for photographic reproduction for chart purposes.

Of the ninety-one catalogue plates exposed only fifty-five were completely successful.

The state of the work stands as follows :—Of the 1512 catalogue plates assigned to the Cape, 1497 have been successfully taken, so that only fifteen remain to be done.

Of the 756 chart plates (even degrees), 503 have been successfully taken, leaving 253 to be done. There remain also 756 chart plates (odd degrees) to be taken, about which the Permanent Committee has not yet decided whether single, double, or triple images of the stars are to be adopted.

Thirty-four catalogue plates, containing 2557 stars, have been completely measured (diameters included) by two independent observers.

The diameters of the discs of the variable star *R Velorum*, together with those of 9 comparison stars, have been measured for all the plates taken to the end of 1895.

A complete investigation of the Réseau Gautier No. 8 has been made, in which the error of sinuosity of every line at twenty-six points on each line has been determined, and all the errors rigorously discussed and tabulated. The results, in the form of a paper by Dr. Gill and Professor Harold Jacoby, will be communicated to the Society.

* These plates are taken on nights of bright moonlight, &c., when conditions are unfavourable for taking chart plates.

Complete Tables of Reduction for the zones $-41°$ and $-42°$ have been computed.

Much time and thought have been given to points connected with the details of the design of the McClean telescope with its accessories and Observatory. H.M. Astronomer has been in almost weekly correspondence with Dr. McClean, a correspondence which has involved the preparation of many sketches and original designs. Dr. McClean has himself laboured indefatigably on the same work, with the result that the designs for all details of the telescope, spectroscope, and Observatory, with its rising floor and dome, are now completed. The building of the Observatory has been begun, and will be ready for the erection of the dome by 1 March. Dr. McClean has provided a developing-room, a study, and store-room, attached to the new Observatory.

The time-signal service has been regularly maintained.

The meteorological observations made at the Observatory in 1895 have been communicated for publication to the Cape Meteorological Commission.

Cambridge Observatory.

The Catalogue of Zone Stars, undertaken by the request of the Astronomische Gesellschaft, taxed nearly all our resources during the past year. It was judged necessary carefully to examine the co-ordinates of each star with their annual precessions and secular variations; and, though this was facilitated by tables constructed not many years after the observations commenced, it has involved much time and care. In accordance with the original arrangement, the printing is done in Germany, to secure uniformity in the volumes of this extensive catalogue of stars in the northern hemisphere, and the proofs of the portion assigned to us are always sent hither for correction and revision.

The press-work has been carried on as far as $17^h\ 35^m$ right ascension, and contains 8,350 places of stars.

Besides this, a comparison of these places with the earlier catalogues—chiefly Bessel, Lalande, and Argelander—has been undertaken. More than 4,000 have thus been identified and compared; giving, in a good many cases, interesting results. In not a few instances there are decided evidences of large proper motion, proved by comparing with ours the places given both in Lalande and Bessel. These and other suspected cases are registered for future observation.

The observations of zone stars during the year number 213; made, for the most part, to settle questions or solve doubts that have arisen in the examination of the Catalogue. There are eight observations of stars which had been compared with Gale's Comet, and of course the requisite number of observations for clock and instrumental corrections.

Another volume of the *Cambridge Observations* is passing through the University Press; and it is hoped that we shall soon be in a position to place in the hands of the printers the larger catalogue, which contains the result of each individual observation of every star in our zone.

The Newall Telescope, Cambridge Observatory.

The Newall telescope has been used for observations on 145 nights in the course of the year 1895.

In the early part of the year the work done was chiefly micrometer work, partly in determining accurately the arc value of a revolution of the micrometer screw for use in the reduction of the observations of the inner satellite of *Mars*, partly in the observation of detail on *Jupiter*; with special reference to the motion (i) of small spots on the surface, and (ii) of the surface near the red spot. The observations of the inner satellite of *Mars* have been published in the *Monthly Notices*, vol. lv. p. 348.

Observations of occultations of stars during the total eclipse of the Moon 1895 March 10 were made under exceptionally favourable conditions of atmosphere. The observations have been published in the *Monthly Notices*, vol. lv. p. 334.

At the end of April the new spectroscope, the design of which, as was stated in last year's Report, had been put in the hands of the Cambridge Scientific Instrument Company in the previous summer, was received at the Observatory, and the adjustment was at once begun. The rest of the year has been devoted almost entirely to work with the spectroscope. This work has necessarily been of a preliminary nature, but the photographs obtained in the later months of the year have been increasingly valuable, as the instrument has been got into better adjustment, and the observers have acquired more experience in using it. Among the objects whose spectra have been especially studied may be mentioned the following:—

α *Boötis*, α *Cygni*, α *Lyræ*, chiefly for adjustment.

α *Aurigæ*, for the determination of velocity in the line of sight with iron comparison spectrum, to compare with the numerous determinations made at Potsdam.

γ *Cassiopeiæ*, with special reference to the bright $H\gamma$ line, the doubleness of which (first announced by Lockyer, *Proc. R.S.* vol. lvii. p. 173) has been fully corroborated.

α *Orionis*, with special reference to the bands in the yellow and green.

Orion stars, with Helium comparison spectra.

Venus, with reference to the possible determination of the period of rotation.

Dunsink Observatory.

Owing to the necessity of bringing our catalogue of stars to completion, and to the heavy work of computing the precessions, secular variations, and proper motions, systematic observations with the meridian circle and chronograph have been discontinued during the greater part of the year, and these instruments have been chiefly used for the determination of the clock correction for the time service to Dublin. In November and December, however, Mr. Martin obtained 160 observations in right ascension and declination of the stars with large proper motion referred to in former reports.

The work on this catalogue commenced in 1885, but has been greatly interrupted since the beginning of the year 1888 by other observations with the meridian circle, by the changes which have taken place in the staff, and by photographic work with the "Roberts" equatorial.

The observations of stars with large proper motions are now fully reduced to the epoch 1890, and are almost ready for the press.

In reducing these observations the clock corrections and the equator point of the circle are both deduced from observations of the *Berliner Jahrbuch* standard stars. In general, however, observations of the nadir point are also made by reflexion from a trough of mercury.

The error of collimation of the meridian circle has been determined 28 times during the year, the level error 65 times, the nadir point (by reflexion) 23 times, and the error of runs 4 times. For determining the error of azimuth 20 transits of polar stars have been taken. For the purpose of determining the error of the Dent sidereal clock 295 observations have been made of the R.A. of the *Berliner Jahrbuch* standard stars, and 52 observations in zenith distance of these stars have been taken to determine the equator point of the circle.

In May the "Roberts" equatorial, which had been in Sir Howard Grubb's workshop, undergoing alteration, for almost a year, was re-erected. This instrument had in the interval been supplied with a new equatorial mounting and clockwork similar to those used at Greenwich, the Cape of Good Hope, and other observatories, for work in connection with the photographic survey of the heavens. The clockwork is of Sir Howard Grubb's latest pattern, with electric pendulum control, acting on a sector of 28 inches radius. Above the cross-head of the declination axis the instrument is in the same condition as when it was presented to the Observatory, except for some minor alterations, such as screw adjustments to the eye-piece slides, the illumination of the spider lines, &c. The new clockwork and mounting have, however,

practically made a new instrument of it, and rendered it capable of taking photographs suitable for measurement.

The work of adjusting this instrument, and experiments of various kinds with it, occupied a large number of nights in May, June, and July, and it was not till towards the end of the latter month that systematic photographic work became possible. Since the end of August this instrument has not been in use, owing to the illness of the Director, but during the months of May, June, July, and August 32 plates were taken, representing a total of 80 exposures of various lengths, from a few seconds to 42 minutes. These include—amongst other objects—4 photographs of the Ring Nebula in *Lyra* and six of η *Cassiopeiæ* for a re-determination of its parallax. A good deal of trouble has been experienced in rating the control pendulum, but in every other respect the instrument now performs in a very satisfactory way.

Only a few plates have been measured at this Observatory during the year. In addition to a few plates, measures of which were necessary for getting the photographic telescope into adjustment—according to the method proposed by the Director, and published in the *Monthly Notices* for December 1893—2 plates containing photographs of Encke's Comet, taken by Mr. W. E. Wilson, at Streete, on 1894 November 30, were measured. The position of the comet as deduced from these plates was published in the *Proceedings of the Royal Irish Academy*, 3rd Series, vol. iii. No. 4.

During the early months of the year the "South" equatorial was used for measuring some double stars in connection with a research as to the effect of the colour of a star on the refraction which it undergoes.

Of these, 21 complete observations, consisting of 8 readings of each of the two screws for distance, and 4 or 6 of position-angle, were obtained.

The partial eclipse of the Sun which took place on March 25 was also observed with this instrument.

In October Mr. Charles Martin, late Senior Computer at Greenwich Observatory, succeeded Mr. Arthur E. Lyster, M.A., as assistant to the Director.

The time service to Dublin has been maintained as in former years; and on the first Saturday of each month the Observatory has been open to visitors, and the 12-inch "South" refractor placed at their disposal.

Durham Observatory.

The transit-circle has been used upon eighty-seven nights for determining the positions of a few stars near the pole that have not been observed for many years.

This Observatory being a second-class meteorological station,

the usual observations have been taken every twelve hours and regularly forwarded to the Meteorological Office.

The equatorial has been used chiefly to explain its functions to students and to show the various heavenly bodies.

Glasgow Observatory.

The 6-inch transit-circle by Ertel was remounted during the spring of the year. Of the old instrument, the axis with telescope and circles and the microscopes have been retained, but the bearings of the pivots, the supports of the microscopes, the balancing arrangement, and the end-thrust are entirely new, and have been made by Messrs. Troughton & Simms. The parts that were replaced have been mounted on a table so as to exhibit the former features of the instrument.

In the new mounting the microscopes are in rigid connection with the standard on which the axis of the telescope turns, and the Vs are formed by pieces of gun-metal dovetailed into the cast-iron standards. The Vs admit of no adjustment, as each of the standards is cast in one piece. They were brought into position by levelling three projecting points on the stone piers to which the standards were finally bolted and cemented. Three months after the fixing the error of azimuth and the inclination of the axis were respectively $0^s{\cdot}02$ and $0^s{\cdot}20$.

The fulcrum of the balancing contrivance is on a level with the top of the stone piers. Small electric lamps of 1 candle-power, one for each of the ten microscopes, illuminate the circles, the light being conducted to the circles by means of glass rods polished at their ends. I may add that the accumulators which supply the current are charged by thermopiles.

Although the instrument was ready for use in July, observing was not begun then, as it was found desirable to replace the micrometer at the eye-end of the telescope. The micrometer had not arrived at the end of the year.

To the 20-inch "Breadalbane" Reflector a new driving clock with Russell control and a new sector have been fitted by Sir Howard Grubb. The various parts of the large spectroscope arrived at the end of October, but it has not yet been mounted on the reflector, owing to some faultiness in one of its parts.

During the year experiments on the controlling and the working of electric dials have been made at the Observatory, at the instigation of the Corporation of this city. It is intended to control from the Observatory eight clocks placed at various centres of the city, and these will in their turn work about three hundred street dials in twenty independent circuits.

The staff of the Observatory has been engaged in reducing and tabulating the old meteorological records, which date from 1843.

The time service and the extensive meteorological work have been carried on as in former years.

Liverpool Observatory.

As in former years, the work of the Observatory has consisted to a very large extent in the determination and distribution of time, and in giving assistance to shipowners and chronometer-makers. The regulations put into force by the Mersey Docks and Harbour Board, to which reference was made in the last Report, have to some extent interfered with this work, as shown by the diminished number of chronometers deposited for test. The number is, however, slightly in excess of last year, and it is hoped in course of time the old figures will again be reached.

The meteorological observations have been continued on precisely the same lines as heretofore, and application is frequently made in salvage and collision cases for scientific information connected with the direction and velocity of the wind. The local importance of such matters has led to the examination of the changes in the barometer readings and direction of wind during severe gales, and it is proposed to publish the result with the Annual Report.

Comet observations have been prosecuted whenever possible. Faye's Comet was repeatedly looked for, but never seen with certainty. Those of Encke, Perrine, and Brooks have all been observed, and the results will be communicated to the Society.

The transit instrument has been occasionally mounted in the prime vertical for the determination of the declination of unknown stars with which the comets have been compared. A series of observations has also been commenced on the diameters of the larger planets, but has been much interfered with by bad weather. These observations began with the view of re-determining the value of the screws of the various micrometers, and especially of their errors, but have been extended to consider the effects of variously coloured illumination of the field on the measures themselves.

Courses of lectures have been given regularly in connection with the classes at University College, Liverpool, and opportunities have been given to the students for practical work with the transit instrument and the equatorial.

Radcliffe Observatory, Oxford.

The work at the Observatory during the year 1895 has included the following:—

The Moon was observed with the transit-circle at every available opportunity; and stars whose places were required either for comet comparisons or as a check upon the results of the Radcliffe Catalogue, 1890, were also observed.

The Barclay Equatorial was used during the year to a greater extent than usual.

Observations were made of Comet Encke on January 8, 18, 21, 23, and 25; that of January 25 being, as far as information is to hand, the latest observation anywhere taken of this comet during its recent apparition. Observations of Comet Swift (1895 August 20) were made on August 24, 28, September 18, 20, 25, 27, October 17 and 24. The results of these observations have been printed in the *Monthly Notices* (vol. lv. No. 3, vol. lvi. No. 2). These results do not adequately represent the time and labour expended on comet work, for careful searches were made for the above comets on many other nights, and also for Comets Faye, Perrine, and Brooks, but the mistiness of the sky or the faintness of the objects prevented their being picked up with the power of the Barclay telescope.

The magnitude of *Nova Aurigæ* was examined at intervals, but no change was detected during the year.

Venus was examined on four nights with variously tinted screens for reported markings on the disc, but nothing unusual was noted, except that on November 18, at $18\frac{1}{2}^h$, a hazy shadow was seen inside the limb, and having apparently nearly the same curvature as the planet's limb. It was considered by the observer as possibly due to contrast between the illumination of the body of the planet and the stronger light of the limb.

The great Nebula of *Andromeda* was also carefully examined. No change was remarked in the large nebula, but the nucleus of the smaller companion nebula was noted as "particularly stellar, as if it were a star surrounded by hazy luminosity," and in contrast to the irresolvable condensation of the larger mass.

Measures of eight double stars have also been made with the Barclay Equatorial during the year.

In conjunction with the heliometer, observations of the occultation of a selected list of stars were made during the total lunar eclipse of March 10. (See *Monthly Notices*, vol. lv. No. 6.)

Considerable attention has been devoted during the year to the early Radcliffe observations made by Dr. Hornsby. The observations of γ *Draconis* with the zenith sector have been reduced and published; and those made with the quadrants and transit instrument during the year 1774 are in process of reduction, and the results promise to be of very considerable value.

The large crayon drawing of the Moon, bearing the date 1795, made by John Russell, R.A., which has been in the possession of the Radcliffe Trustees for many years, having recently shown some traces of mildew, has been cleaned and reframed; and photographs have been taken and sent to the Society. (See *Monthly Notices*, vol. lvi. No. 3.)

A volume of the Radcliffe Astronomical and Meteorological Results for the years 1888 and 1889 has nearly passed through the press.

The meteorological observations and registrations have been carried on as usual.

The University Observatory, Oxford.

During the year 1895 the energies of the Observatory have been directed chiefly to the work for the Astrographic Chart. The number of catalogue plates obtained was 337, bringing up the total number of regions photographed to 695.

Eighty-seven plates have been measured during the year. It is hoped that this number may be largely increased in future years, when an additional micrometer has been received from Mr. Simms. The total number of stars measured on these plates is 27,653. A description of the micrometer and methods of reduction are given in the *Monthly Notices*, vols. liv. and lv.

By the kindness of Sir Robert Ball, advance proofs of the *Cambridge Zone Catalogue* (R.A. $0^h - 5^h$) have been received, and the places brought up from 1875·0 to 1900·0 (2,350 stars) for use in the reduction of the catalogue plates.

Some experiments have been made to test the suitability of paper prints for accurate measurement, with encouraging results (*Monthly Notices*, vol. lvi. p. 28).

Some attention has been paid to the photography of minor planets with a view to the determinations of place or parallax. Nineteen plates, with from two to fifteen exposures on each plate, were taken of the planets *Pallas* (3) and *Eunomia* (15).

One of the *Pallas* plates, with exposures ranging over $5\frac{1}{4}$ hours, has been completely measured, and though the range of parallax factor is not large enough to give a result of any great value in itself, the accuracy of the method is clearly indicated; and it has been demonstrated that the method of reduction by rectilinear co-ordinates makes it possible to obtain a planetary parallax from a photographic plate with very little numerical labour. The plates of *Eunomia* have been only recently obtained, and the measures are not yet complete; but the conditions were much more favourable than for *Pallas*.

At the request of Dr. F. McClean three plates were exposed on the same region with different diaphragms in front of the O.G. of the Astrographic Telescope, the exposures, in numbers 14, 16, and 15 respectively, being arranged to compensate the diminution of aperture; and the plates were sent to Dr. McClean. A general examination of the plates assisted him in deciding some questions relative to the new telescope which he is presenting to the Cape Observatory; but a more complete discussion would be of interest and will be undertaken.

At the request of Mr. Newall, the distance between two stars in the Pleiades, suitable for the evaluation of a micrometer screw, was accurately determined (*Monthly Notices*, vol. lv. p. 419).

The Barclay Transit Circle was returned by Messrs. Troughton & Simms 1895 January, and mounted before the end of that

month. Since then observations have been made of collimation, 166; of level, 176; of polar stars, 80; and of clock stars, 254. Besides these observations, the wire intervals and the values of R.A. and Z.D. screws have been determined. A considerable number of these observations were made by Mr. A. J. Walker, M.A. (New College), who took charge of the instrument during the October Term.

Lectures on elementary mathematical astronomy were delivered in the Hilary and Michaelmas Terms. Owing to the unsatisfactory position of astronomy in the University curriculum, there has been hitherto (during recent years) no demand for more advanced lectures; but a change has been effected during the past year which will, it is hoped, have beneficial results in attracting students to a more thorough acquaintance with the science.

A collection of photographs was lent to the Imperial Institute on the occasion of the Photographic Exhibition.

The arrangements for the eclipse expeditions of 1896 have occupied some time, and will probably claim a good deal of attention in the coming year.

Temple Observatory, Rugby.

The usual scholastic work has been continued during the past year, and this shows a tendency to increase. In original work, the measurement of position and distance of double stars has been continued, but the time left available for this has not been so much as in past years. It is hoped that the spread of astronomical interest amongst the boys will compensate for absence of other work.

Stonyhurst College Observatory.

The routine work of the meteorological and magnetical department has been carried on as usual, and the continuous recorders have been working well.

The new "Stonyhurst Sunshine Recorder," made by Messrs. Newton & Co., has been tested by comparisons with the "Campbell-Stokes" Recorder of the Meteorological Office, and has been found to work very satisfactorily. Some improvements have been suggested in the mechanical construction of the instrument, and have been accepted by the makers.

The instruments for absolute measures of the magnetic elements have been compared with the instruments adopted as standards by the Physical Section of the last meeting of the British Association for the Advancement of Science, with the object of co-ordinating the measures obtained at the several magnetic observatories of the United Kingdom. The results of these comparisons are expected at the next meeting of the same Association.

A partial reduction of the magnetograms to figures has been commenced: to the extent of four readings for each day—viz. maximum and minimum horizontal force and westerly direction, and the measures at 4 A.M. and 4 P.M. This work is well advanced for the past year, and will be extended to previous years, according as time allows.

Drawings of the solar spots and faculæ have been made on nearly all the days on which it was possible without too great an expenditure of time in waiting for clear intervals. And in connection with these drawings, photographs of the H–K. region of the solar spectrum have been taken with the grating spectrograph, in order to observe how closely the double reversals by integrated solar light follow the disturbances of the solar surface.

The spectroscopic experimental work with the Perry Memorial Objective was not completely finished until the end of April. These experiments represent a large number of photographic stellar spectra. But the plates are of no value for measurements, having been taken with thirteen different collimators and seven different camera lenses. Several prisms have also been tried, but not all photographically. The finally adopted arrangement is a slitless spectrograph, of one (or two) direct prisms of three components, with a concave compound collimating lens to bring all the rays between D and *h* parallel through the prism. All the parts of the spectrograph are the work of Mr. Hilger.

A very satisfactory wave curve has been plotted for the one-prism spectrum, and another will shortly be made for the pair of prisms.

A new series of photographs of the spectrum of β *Lyræ* has been obtained, consisting of seventy-seven plates. And of these, thirty-nine, or three good plates for each day of the light period, have been selected for measurement. The measurements were not complete before they were necessarily suspended in favour of the regular work of the Observatory, which is always more pressing in the first months of a new year.

A double series of photographic spectra of the brighter stars has been commenced—viz. with the single prism and with the pair of prisms. A wave-length map of the spectral lines of forty-three of the bright stars, photographed with the old 8-inch objective, was finished early in the year; but it was not thought well to offer it for publication until a more complete series was finished with the larger light collector.

Dr. Common's Observatory, Ealing.

The work of converting the 5-foot Newtonian Reflector into an Oblique Cassegrain has been in progress during the last year. In order to find the best results further experiments have been carried on, involving the construction of various convex surfaces.

In the workshop two 16-inch plane mirrors have been made for the Cœlostats, for use at the next total solar eclipse, and one 16-inch has been made for the new telescope of the Cambridge Observatory, as well as others of less size.

Beyond some experimental photographs no astronomical work has been done of any importance.

Mr. Crossley's Observatory, Bermerside, Halifax.

The usual astronomical and meteorological observations were made during the year just closed. The *Jupiter* observations up to May have already appeared in the *Monthly Notices.* A 4½-inch photo-visual object-glass by Messrs. T. Cooke & Sons, of York, has been mounted here and carefully tested, visually, with excellent results, proving itself at least equal to a 5-inch object-glass of the usual kind.

Wolsingham Observatory. (Rev. T. E. Espin's.)

The new Observatory was not completed till April, and work was re-started on April 14. The total number of observations of variable stars, and with the spectroscope, is 1,113. The observations of stars with remarkable spectra have been forwarded to the *Astronomische Nachrichten.* This list contains: (1) Nos. 1,058 to 1,179; of these 18 are probably of Type IV.; the observation of 51 stars from Krüger's "Catalog der Farbigen Stenre," and various other objects to a total of 210; (2) 132 stars observed as III.! (3) 458 stars observed as III. or II.—a total of 800 objects.

Observations tending to confirm the variation of the following stars have been made:—

Name.	R.A. 1900 h m	Decl. ° ′	Var.	Type.
EsB 184	6 17·8	+25 4	8·9–9·7	IV.
EsB 189	6 20·3	+19 8	8·8–9·5	IV.
EsB 281	8 49·7	+17 36	6·4–7·9	IV.
EsB 357	12 35·8	+56 23	8·0–8·8	III.
Es 1021	19 42·9	+15 48	8·8–10?	III.?
Es 1169	19 52·4	− 2 11	8·4–?	III.
EsB 679	20 33·4	+17 55	6·0–6·7	III.

Mr. Peek's Observatory, Rousdon, Lyme Regis.

The establishment continues in good working order, and observations have been made on 155 nights, this being rather less than the average number. During January and February on

several clear nights the cold was so intense that the equatorial clock ceased to work, and the dome could not be rotated or the shutter raised. During the latter half of December the sky was almost continuously overcast.

The 6·4-inch Merz Achromatic Telescope has been kept regularly at work on long-period variable stars, and 518 determinations of magnitude have been secured, which is fully the average number.

The Red Star discovered by the Rev. T. E. Espin, 1894 November 30, has been added to the working list, and found to be a long-period variable. The observations show it to have ranged from 8·5 magnitude on January 8 to 10·3 magnitude on August 15, rising again to 7·9 by 1895 December 31.

Transit observations have been taken as often as required.

The lunar eclipse of March 10 was observed under very favourable conditions, special attention being directed to the occultations of the list of selected stars given in the *Companion to the Observatory.* Seven disappearances were secured.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The work of photographing nebulæ and clusters of stars has, as in former years, been pursued, and the following list of the photographs, with exposures of 30 minutes and upwards, is given in continuation of the former lists, the last of which was published in the *Monthly Notices*, vol. lv. pp. 223, 224. The negatives are all available for reference :—

	R.A.	Decl.	Expos.
	h m	° ′	m
Tycho's *Nova* in Cassiopeia	0 16	+63 15	90
Great Nebula in Andromeda	0 36	+40 30	90
Neb. in Cetus	0 38	− 8 48	90
Neb. in Cassiopeia	0 47	+56 2	57 and 75^{m}
Region of γ Cassiopeiæ	0 50	+60 7	90 and $2^{h}\ 12^{m}$
Neb. M. 33 Trianguli	1 28	+30 7	$2^{h}\ 15^{m}$
Neb. ♅ I. 152 Piscium	2 2	+10 30	54
Clusters in Perseus	2 11	+56 38	90
Neb. ♅ I. 102 Eridani	2 33	− 7 8	90
Neb. ♅ I. 63 Eridani	2 36	− 8 41	90
Cl. ♅ VIII. 61 Aurigæ	5 1	+36 55	30
Nova Aurigæ	5 24	+30 23	3^{h}
Neb. M. 1 Tauri	5 28	+21 57	60
Cl. ♅ VIII. 26 Geminorum	5 54	+23 18	30 and 60^{m}
Cl. ♅ VIII. 9 Geminorum	6 23	+16 46	3

	R.A.		Decl.		Expos.
	h	m	°	′	m
Neb. in Monoceros	6	25	+ 5	0	54
Cl. H VIII. 3 Monocerotis	6	29	+ 8	26	30
Cl. H VIII. 50 Monocerotis ...	6	29	+ 5	26	30
Cl. H VIII. 48 Monocerotis ...	6	32	− 1	22	30
Neb. near 15 Monocerotis	6	35	+ 10	0	90 : 2^h and 3^h
Cl. H VIII. 31 Monocerotis ...	6	42	− 3	3	30
Cl. H VIII. 71 Aurigæ	6	42	+ 41	11	30
Cl. H VI. 2 Geminorum	6	49	+ 18	9	30
Cl. H VIII. 40 Geminorum	7	1	+ 27	22	30
Cl. H VIII. 33 Monocerotis ...	7	3	− 10	29	30
Cl. H VIII. 36 Canis Majoris ...	7	23	− 11	32	30
Cl. H VIII. 11 Geminorum	7	23	+ 13	59	30
Cl. M. 47 Argûs	7	50	− 15	8	30
Neb. H I. 249–50 Ursæ Majoris ...	9	1	+ 60	42	90 and 3^h
Neb. H I. 2 Hydræ	9	5	+ 7	28	90
Neb. H I. 167 Lyncis	9	7	+ 40	33	90
Neb. H I. 216 Ursæ Majoris ...	9	9	+ 69	39	77
Neb. H I. 113, 137 Lyncis	9	15	+ 34	35	90
Neb. H I. 260 Ursæ Majoris ...	9	21	+ 62	57	90
Neb. H I. 114 Leonis Minoris ...	9	36	+ 32	20	90
Neb. H I. 61 Hydræ	9	37	− 3	10	90
Neb. H I. 285 Ursæ Majoris ...	9	38	+ 68	24	90
Neb. H I. 78 Ursæ Majoris	9	41	+ 72	46	90
Neb. H I. 115 and V. 26 Leonis Minoris	9	43	+ 33	58	72
Neb. H I. 286 Ursæ Majoris ...	9	55	+ 69	15	90
Neb. H V. 47 Ursæ Majoris ...	9	55	+ 56	12	90
Neb. H I. 79 Ursæ Majoris	10	8	+ 73	56	90
Neb. H I. 283 Draconis	10	17	+ 75	12	40
Neb. H I. 86 Leonis Minoris ...	10	21	+ 29	3	90
Neb. H I. 87, 88 Leonis Minoris ...	10	56	+ 29	0	90
Neb. H V. 46 and M. 97 Ursæ Majoris	11	7	+ 55	56	4^h
Neb. H I. 29 Leonis	11	9	+ 13	23	78
Neb. H I. 121 Virginis	11	55	− 0	30	90
Neb. H I. 33 Virginis	12	2	+ 10	58	70
Cl. M. 13 Herculis	16	38	+ 36	39	30 and 60^m
Cl. M. 9 Ophiuchi	17	13	− 18	24	30 and 60^m
Neb. H VI. 41 Draconis	17	33	+ 75	48	60
Cl. M. 24 Clypei	18	12	− 18	28	60 and 2^h
Cl. H VIII. 72 Serpentis	18	22	+ 6	30	40

	R.A.		Decl.		Expos.
	h	m	°	′	m
Neb. M. 57 Lyræ	18	49	+32	54	2^h
Cl. ♅ VII. 19 Aquilæ	19	2	+4	4	60
Neb. in Aquila	19	6	+0	52	90
Cl. *h* 2035 Aquilæ	19	11	−1	6	64
Cl. ♅ VIII. 21 Anseris	19	23	+24	56	50
Cl. ♅ VI. 38 Aquilæ	19	26	+9	0	60
Cl. *h* 2046 Vulpeculæ	19	36	+26	34	60
Cl. *h* 2048 Cygni	19	37	+39	56	60
Stars in Cygnus	19	45	+35	30	60
Cl. *h* 2053 Draconis	19	46	+59	10	60
Cl. ♅ VII. 9 Vulpeculæ	19	46	+22	50	60
Cl. ♅ VII. 59 Cygni	19	59	+43	37	60
Cl. ♅ VIII. 56 Cygni	20	19	+40	27	60
Cl. ♅ VII. 8 Cygni	20	30	+27	58	60
Neb. ♅ V. 15 Cygni	20	41	+30	20	67
Cl. ♅ VIII. 76 Cygni	20	51	+46	53	60 and 2^h
Neb. ♅ V. 14 Cygni	20	50	+30	50	$1^h\ 37^m$
Neb. ♅ I. 52 Equulei	20	56	+15	47	40 and 90^m
Region about ξ Cygni	21	1	+43	31	63 and 90^m
Cl. *h* 2107 Cygni	21	7	+45	15	60
Cl. ♅ VI. 32 Cygni	21	27	+51	7	60
Cl. ♅ VII. 52 Cygni	21	28	+46	38	90
Cl. M. 39 Cygni	21	28	+47	58	60
Neb. in Cepheus	21	35	+56	59	$2^h\ 48^m$
Nova Cygni	21	37	+42	18	2^h
Cl. ♅ VII. 66 and Neb. ♅ IV. 75 Cephei	21	42	+65	27	$2^h\ 5^m$ and 3^h
Cl. *h* 2141 Cephei	21	55	+54	19	60
Neb. ♅ II. 240 Pegasi	23	58	+15	33	$2^h\ 49^m$

Seven photographs of the eclipse of the Moon on March 10 were taken, and during totality the full disc, with some details, are shown on the plates, and upon two of them the trails of τ (and *comes*) *Orionis*, both at disappearance and at reappearance, are visible. Trails of other stars down to 9½ magnitude are also shown.

Considerable time has been occupied in the investigation of the relative efficiency of the 20-inch reflector and of portrait lenses in the delineation of celestial objects, and a report upon the results obtained is prepared and may be submitted to the Society.

The Earl of Rosse's Observatory, Birr Castle.

During the past year the determinations of lunar heat have been resumed, as opportunity afforded, with somewhat improved apparatus. No opportunity, however, has occurred for observing during a lunar eclipse.

Some experiments in astronomical photography have been proceeding. Great difficulty has been experienced in these from obscuring of the apparatus during prolonged exposures, but these hindrances have at last been overcome. In our uncertain climate, however, the opportunities for long exposures are not many. There has probably been at least an average of clear sky during the year, but an unusually large proportion of this occurred during the summer months, when no observing was going on.

The meteorological observations have been continued as usual.

Mr. Wilson's Observatory, Daramona, Streete, Westmeath.

During the past year a number of experiments have been carried out, and are still in progress, to find out the best method of detecting when a slight shift takes place in the 24-inch mirror on its supports when the telescope is used for long-exposure photography. This defect, to which all reflectors are more or less liable, is the most serious drawback against their use for stellar photography as compared to refractors.

During the spring the 24-inch was used by Professor Minchin with his photo-electric cells to determine the electromotive force of the light of some of the stars. The results have been published in the *Proceedings of the Royal Society*, vol. lviii. The experiments on the radiation of heat from Sun-spots have been carried on by means of the large heliostat. The spots have greatly diminished both in size and number during the year. A 4-inch photo-heliograph has been mounted, and a solar photograph is taken at the time that the solar radiation is being measured, in order that a permanent record may be kept of the positions and sizes of the spots. Some fine negatives have been obtained by its use.

The weather has been very cloudy, particularly during the latter part of the year.

Hongkong Observatory.

Hourly observations and continuous meteorological records, weather forecasts, storm warnings, investigations of typhoons, magnetic observations, and the public time service have been continued as usual. Eleven annual volumes have now been pub-

lished, and the twelfth volume is progressing. Observations of shooting stars have been made by the Director, and sixty-three radiants, many of them southern ones, have been determined. With the Lee Equatorial, double stars have been observed by the Director, the angles with the old wire micrometer, and the distances with the spherical crystal; but this instrument has seen its best days, and there is no dome over it, so that it has to be dismounted in bad weather. It is intended to bring the orbits of double stars calculated at Markree up to date, and correct the elements by the method of least squares. A commencement has been made with α *Centauri* and γ *Virginis*, and the observations of all the stars in question contained in books in my possession have been tabulated. Double-star observers are invited to forward their observations either in printed form or in manuscript.

Madras Observatory.

As for several years past, the work of the Observatory has been confined as far as possible to the reduction and publication of the old observations.

Considerable progress has been made with the General Star Catalogue, and the mean places for 1875·0 have been deduced for the first four hours.

The investigation of the circle errors, begun last year, has not yet been completed, as it was found necessary to send the microscopes home to have the screws, which were much worn, replaced by new ones. This has now been done, and the work is again in progress.

During the year the Government Astronomer drew up detailed plans, in consultation with astronomers at home, for the new Kodaikanal Observatory, and in October the foundation-stone of the Observatory was laid by H.E. Lord Wenlock, but the buildings have not made much progress.

The Government of India having accepted, as a trust, the G. V. Jugga Row Observatory, at Vizagapatam, a committee has been appointed to administer the trust, and the Government Astronomer has the supervision of the astronomical work. The principal instruments at the Observatory are an excellent 6-inch equatorial and a small photographic telescope. No regular observations have yet been begun, but it is intended, as soon as the instruments have been put in good order, to undertake comet work as a special subject.

Natal Observatory.

The work of the Natal Observatory during the past year has been mainly routine work, the Astronomer having been absent on leave in Europe for the greater part of the year.

The new Tables of the Moon, forming a supplement to Hansen's Tables, are being computed, the data on which they are compiled serving to bring the tables into harmony with observations during the entire period 1680–1894, the errors of short period being almost completely eliminated.

Sydney Observatory.

During 1895 the usual work has been carried on with the meridian circle. The weather has, however, been exceptionally bad. Bush-fires have been very prevalent during August, September, and October, owing to the drought and strong winds; hence the smoke has been so thick that the horizon was often not more than a mile distant. Cloud also has been very abundant, and only 96 nights have been clear.

Meridian Circle.—With the meridian circle 1,488 transits have been taken, 408 of these being transits of the Sun, and the remainder of stars. Eight hundred and fifty-three north polar distances have been observed. Fifty-three of these were stars specially selected by Sir Charles Todd with a view of making a new determination of Australian latitudes. In this work we have taken a part with Melbourne and Adelaide. The remaining stars are reference stars for our photographic zone.

Azimuth of the meridian circle has been determined 85 times.

Collimation	299
Level	373
Nadir	363

A series of observations to determine the flexure of the meridian circle has been commenced. Fifty-four determinations have been made, and so far confirm the old value. The computations of 1895 observations are well advanced. The Government printer has not found time to publish another volume of the meridian work, which is waiting for him.

Equatorial.—Owing to cloud, smoke—already referred to—and visitors, only 64 evenings were available for the measurement of double stars. Fifty-eight have been measured. In doing this 751 settings for position-angle and 831 for distance have been made. Five stars supposed to be double have been carefully examined several times without detecting companions. The occultation of *Antares* by the Moon was observed in both phases and the results published.

Star Camera.—At the end of 1894 only 70 plates required to be taken in order to complete those for catalogue stars in our zone. Of these 59 have been taken; the other 11 were passed by accidents of cloud and weather. The total number of photographs of stars taken during the year is 502. Of these 381 are

chart plates, 59 catalogue plates, and 58 for various purposes —the investigation of star clusters and the retaking of a number of catalogue plates which were taken two or three years since, the object being to see if the same number of stars would be found on both sets of plates. Reference has already been made to the weather as the cause of the short amount of work; it has, however, told more on the star camera than on the other instruments, because there were many hazy nights, when the stars could be seen, but not photographed, the reason being that in long exposures the haze reflects enough of the city light to fog the plates. Half an hour is the exposure given to chart plates in good weather, but this has been extended in hazy weather or unsteady definition. A few special observations were made to determine the actual amount of motion in the star images on nights of bad definition. Some nights were so bad that a double star distance $6''$ could not be divided with the large equatorial; the two looked like one spot of light. On a good night this telescope will readily divide a pair at distance $0''\cdot5$. Photographic star discs are enlarged by this motion in the atmosphere; frequently they were three times as large in diameter as they ought to be. The light was therefore distributed over nine times the surface, and took nine times as long to photograph; so that a star of the 11th magnitude, which on a good night is photographed in one minute, would take nine minutes; and practically it is found that satisfactory photographs of stars cannot be obtained upon nights of such bad definition. It being impossible to take chart plates whenever the Moon is at all bright, the photographer has been engaged in making lantern slides of star groups, with great success. They are the finest I have seen.

Zone Time.—Zone time was adopted in this colony on 1895 February 1—that is, the time of the meridian 150° of longitude east of Greenwich.

Meteorology.—The meteorological work has been carried on as usual—a large increase in the number of observers, and a corresponding expansion of the work.

General.—During the year 4,600 copies of various publications have been distributed. These are chiefly meteorological, but include the chart of circumpolar stars, &c.

Visitors.—The number of visitors to the Observatory persistently increases, and is becoming a very serious tax upon the staff. The majority come to see the Observatory in the daytime; the others come at night, and are a still more serious difficulty, for the telescope had to be given up to them on thirty-one nights. The total number is 1,050. In addition to these, 459 persons came to see me personally on business connected with the Observatory, and 123 letters asking for information have been received, to answer which occupied the time of one clerk 187 hours. However much this tax on the time of the Observatory staff is to be deplored, it is at present impossible to avoid it.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.

Although much cloudy weather was experienced at both the beginning and the end of the year 1895, a fair amount of work was accomplished. The local sidereal time was determined on 184 nights, and for this purpose 957 transits of stars with a declination not exceeding 40° were observed. The determinations of the level, collimation and azimuth errors of the transit instrument were 454, 52, and 159 respectively. The level and azimuth errors have undergone great progressive changes during the year. Relatively the eastern pivot fell slowly from the beginning of the year till towards the close of February. From that time it gradually rose till about March 23; but subsequently it fell till the end of the year, and it was found necessary to raise it by adjustment no fewer than fourteen times during that period. The north end of the axis of collimation moved persistently westward throughout the year, and at the close the azimuth *west* had attained to nearly a minute of arc. When the steadiness of the instrument for some years past is taken into consideration these changes are remarkable. The behaviour of the standard sidereal chronometer has been satisfactory, the mean daily gaining rate being 3·05 seconds.

In the extra-meridian department the following work has been done. Sixty-four phases of lunar occultations of stars have been observed, comprising thirty-five disappearances at the dark and ten at the bright limb, and fourteen reappearances at the dark and five at the bright limb. Twelve *Nautical Almanac* stars, of which *Antares* on May 10 was one, were observed in both phases. B.A.C. 6127, a star of the 5th magnitude, was well observed with the 8-inch telescope in both phases, and in full sunlight, on August 29. The details of this interesting observation are given in the *Observatory* for 1895 November. During the past thirty-two years 691 occultation phases have been observed, and the year 1895 presents the greatest number secured in any one year during that period. The thanks of myself, and astronomers generally, are due to Mr. Joseph Brooks, F.R.A.S., the officer in charge of the local trigonometrical survey, for his kindness in providing the Observatory with prediction calculations of occultations for the year. The series of observed occultations for 1873–76 was used some years ago by Dr. Auwers for the determination of a fundamental meridian for Australia. The series for 1864–70 is now in the hands of another astronomer for a similar purpose, and it is hoped that the much longer series for 1877–95, which has been obtained with better instrumental means, will leave little to be desired in the way of data for the determination of Australian longitude.

Filar micrometer comparisons of *Jupiter* and 1 *Geminorum* were made on the 8-inch equatorial on January 5 and 10. Similar comparisons were made of *Saturn* with κ *Virginis* on May 6, 7, 9, 13, 15, 16, and with 96 *Virginis* on August 4, 8, 9, 10, 11, 12. The minor planets *Ceres* and *Hebe* were also compared micrometrically with neighbouring stars on fourteen and eleven nights respectively, the former in pretty high south declination, and the latter at the request of Dr. Luther, of Düsseldorf.

In consequence partly of the want of ephemerides, but mainly of the cloudy state of the skies in December, nothing was seen of the comets discovered by Perrine and Brooks. A brilliant comet was reported to be visible in the south-west at several places in Victoria and South Australia, but no chance was afforded here for getting a view of the stranger. It probably passed quickly into the northern hemisphere.

Observations of the phenomena of *Jupiter's* satellites were made in February, March, April and May. The earliest visible eclipse of the fourth satellite for the current cycle was partly observed on April 11, the reappearance occurring $13^{m}\ 17^{s}$ before the time given in the *Nautical Almanac.*

Measures of seventeen well-known southern double stars have been made, comprising forty-five nights, 815 settings for position-angle, and 348 for distance. The results for α and γ *Centauri* and γ *Coronæ Australis* have been sent to Dr. See, of Chicago, and those of α *Centauri* to Dr. Doberck, of Hongkong, in accordance with applications from those astronomers.

η *Argûs* was examined on a few occasions and a well-connected series of comparisons of *R Carinæ* was obtained, from which it appears that the maximum of this variable was attained on May 13, =5·1 of the magnitude scale of the *Uranometria Argentina.* This was brighter than the maximum of 1894 by half a magnitude, and is the eleventh satisfactorily determined at Windsor since 1879. A comparison of the Cordoba observations in 1871 with those at Windsor in 1895 gives a mean period of about 311 days from maximum to maximum. This is a day less than that deduced from the comparisons down to 1886.

The meteorological observations have been regularly made during the year, and the last winter proved to be the coldest experienced at the Observatory for thirty-three years. The abstracts for 1891-92-93-94-95 are now nearly ready for the printer.

Finally, all the astronomical observations and their reductions have been made by the proprietor, and nearly all the meteorological observations, with their reductions, have also been made by him.

Lovedale, South Africa. (Mr. A. W. Roberts's.)

The work here has been the observation of variable stars south of $-30°$ Decl. The systematic search for short-period variables carried on in previous years was given up in 1895, as the number of known variables had so increased that only the regular observation of such stars could be undertaken.

Two new variables, however, were discovered, one in *Crux* and the other in *Vela*. The stars *X Carinæ* and *R.S. Sagittarii* were proved to be of the Algol type. The former star was discovered at Lovedale and the latter at Cordoba, by Dr. Gould.

Observations were made on 114 nights, the particulars being as follows:—

Algol variables (4 stars)	901
Short-period variables (17 stars)	1296
Regular long-period variables (16 stars)	594
Suspected variables (15 stars)	102
	2893

Each of the above observations is the mean of two, one direct and the other reverse. This mode of observation has been adopted to eliminate "position error."

As each observation also means, on the average, the determination of five comparison stars, the individual determinations of magnitude throughout the year are considerably over 30,000.

The position of the Observatory is—

$$\text{Long. } 1^{h}\ 47^{m}\ 24^{s}{\cdot}5 \text{ E.}$$

$$\text{Lat.} -32^{\circ}\ 46'\ 30''$$

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1895.

Twelve new planets were discovered during the past year, as follows :—

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1895.	Discoverer.	Place of Discovery.
BP	399		Feb. 23	Wolf	Heidelberg
BQ	...		23	"	"
BU	400		Mar. 15	Charlois	Nice
BT	401	*Ottilia*	16	Wolf	Heidelberg
BW	402		21	Charlois	Nice
BX	403		May 18	"	"
BY	404		June 20	"	"
BZ	405		July 23	"	"
CB	406		Aug. 22	"	"
CC	407		Oct. 13	Wolf	Heidelberg
CD	408		19	"	"
CE			Dec. 9	Charlois	Nice

It is possible, however, that CE may be identical with (188) *Menippe.*

The following planets, discovered in 1894, but not numbered at the date of the last Report, have since received permanent numbers :—BE 391, BF 392, BG 393, BH 394, BK 395, BL 396, BM 397, BN 398. BD, BO, do not receive permanent numbers, not having been sufficiently observed. (318) has been named *Magdalena*, (319) *Leona*, (331) *Etheridgea*, (336) *Lacadiera*, (369) *Aëria*, (384) *Burdigala*, (392) *Wilhelmina*. The unappropriated number 330 has been assigned to 1892 X, discovered by Wolf 1892 March 18. The planets provisionally named BR, BS, BV, CA, CF, CG, were found to be identical with (379), (333) *Badenia*, (203) *Pompeia*, (336) *Lacadiera*, (352), (175) *Andromache* respectively. (403) has an orbit somewhat resembling that of the missing planet (156) *Xanthippe*, and was at first supposed to be identical with it. A systematic search was made for (132) *Aethra*, but without success. The period of (401) *Ottilia* is almost

exactly half that of *Jupiter*, which will make the theory of its motion interesting.

Mr. B. M. Roszel has recently published an investigation of the total mass of the first 311 minor planets (*Johns Hopkins University Circular*, 1895). He uses Mr. Barnard's measures of *Ceres, Pallas*, and *Vesta*, and assumes that the remaining planets have the same albedo as *Vesta*, the mean density of the group being assumed the same as that of *Mars*. He thus determines the mass of the group as ·003 of that of *Mars*. On the more probable assumption that the mean albedo of the group is only $\frac{1}{3}$ of that of *Vesta* (*vide* Mr. Barnard's paper, *Monthly Notices*, vol. lvi. p. 2) the resulting mass would be about ·008 of that of *Mars* or $\frac{1}{14}$ of that of the Moon.

General Parmentier has published an analysis of the distribution of the orbits of the first 390 minor planets (*Bulletin of the Astron. Soc. of France*, 1895 March). The four smallest mean distances are (330) dist. 2·09, (323) *Brucia* 2·16, (149) *Medusa* 2·17, (244) *Sita* 2·17. The three largest are (279) *Thule* 4·26, (361) 3·96, (153) *Hilda* 3·96. The gaps at distances corresponding to $\frac{1}{2}$ and $\frac{1}{3}$ of *Jupiter's* period still persist, though the planet (401), since discovered, occupies the first-mentioned gap. There is a less strongly marked gap at a distance corresponding to $\frac{2}{5}$ of *Jupiter's* period. But gaps formerly noted at distances corresponding to $\frac{2}{7}$ and $\frac{3}{7}$ of *Jupiter's* period have been filled by recent discoveries, and can no longer be said to exist. The greatest density of the group is at distance 2·80, exactly that indicated by the law of Bode or Titius. *Ceres, Pallas*, and *Juno* all approximate to this distance. Of the 390 orbits discussed, 384 have mean distances between 2·16 and 3·48.

The following planets, discovered previously to the end of 1893, have been observed at one opposition only :—99, 132, 155, 156, 157, 188, 193, 220, 285, 290, 293, 296, 307, 309, 310, 314, 315, 316, 319, 320, 323, 327, 328, 330, 332, 339, 340, 341, 342, 343, 353, 355, 356, 357, 358, 359, 360, 361, 362, 364, 365, 367, 368. All the other planets from 1 to 378 inclusive have been observed at two or more oppositions.

The following planets, discovered in 1894, have already been observed at two oppositions :—379, 380, 381, 384, 387, 389. 396 is probably identical with a planet discovered by Palisa on 1887 April 21, but not numbered at that time.

During the year ending 1895 November, Professor Wolf found that of the planets registered on his plates one was new for every 6·3 that were known. During about the same period M. Charlois photographed one new planet for 4·0 known planets. These figures suggest that the number of planets brighter than the 14th magnitude still to be discovered is not very large; too much stress, however, must not be laid on this expectation, since six new planets have already been discovered during the first three weeks of 1896.

A. C. D. C.

The Comets of 1895.

The year 1895 has not been rich in either cometary discoveries or observations. At the beginning of the year the very faint comet of Swift was still visible in some of the larger telescopes, but though observations are very scanty, it is hoped that the later positions may decide the interesting question of the identity of the comet with that of De Vico, 1844, I. Encke's comet was also visible, but was soon lost by its approach to the Sun.

The first cometary discovery of the year is due to Professor L. Swift, of Echo Mountain, California, who, on August 20, detected a faint comet in *Pisces*. For a short time after its discovery it increased slightly in brilliancy, but always remained an inconspicuous object, and was not generally observed after October. But the observations are sufficient to establish not only the fact of its periodic character, but to indicate a possible connection with the well-known comet of Lexell. The most accurate orbit yet published is probably that from M. Schulhof, but in this the uncertainty in the period (7·19 years) amounts to fifteen days. It is evidently too early to express an opinion, and the question is further complicated by the close approach which the comet can make to both *Mars* and *Jupiter*. The distance between the orbit of *Mars* and that of the comet is less than 0·007 R in longitude 15°, while in longitudes 179° and 135° the orbit is separated from that of *Jupiter* by 0·08 R and 0·24 R. respectively. With an inclination of only 3° such approaches must be anticipated. In 1886, however, if Schulhof's elements are trustworthy, the comet and *Jupiter* were distant from each other by less than half the distance of the Earth from the Sun, and the orbit of the former must have suffered severe perturbation. A comparison between Schulhof's elements and the elements which Lexell's comet may, very possibly, have had after the excessive perturbations of 1779 is given below.

	Swift's Comet.		Lexell's Comet.	
Long. of Perihelion ...	338·1°	Eq. 1895·0	337·7°	Eq. 1770
„ Node	170·3		167·1	
Inclination	3·0		4·9	
Excentricity	0·6515		0·6782	
Semi-Axis Major	3·724		3·874	

To which may be added as a matter of interest,

	Swift's Comet.	Lexell's Comet.
Tisserand's Criterion ...	0·493	0·480
Long. of closest approach to ♃	179·5	184

The one condition unfavourable to the assumption of identity between the two comets is the slight alteration in the longitude of the node. With the small inclination that this comet has, the

retrogression of the longitude of the node should be considerable, and can only be explained by the suggestion that the node has really retrograded through 357°. Unfortunately, the period and the position of the orbit are such that no return favourable for observation can be expected before 1931, and to settle this question with certainty and to ensure its re-discovery with confidence the period should be known with an error of not more than one day. It is questionable whether the observations secured at this appearance possess the necessary accuracy.

The next comet to be noted was that of Faye, which, however, does not actually reach perihelion till March of this year. As the chances of observing it in the autumn of 1895 were favourable, a finding Ephemeris was prepared by Dr. Folke Engström, which led to its detection at the Nice Observatory on September 26 by M. Javelle. At this date the theoretical brilliancy was about a maximum, but the alteration in brightness is very slow and gradual. The few observations that have been made have been confined to the larger instruments, and in these with difficulty. The perturbations do not seem to have been rigorously computed for this return, but are slight. The effect on the period is less than five days.

A bright telescopic comet was discovered on November 17 by Mr. Perrine, of the Lick Observatory, in the morning sky and approaching the Sun. The increase in brilliancy was very considerable, but its close proximity to the Sun prevented the comet being seen under the best conditions. It became visible to the naked eye, and in the telescope the tail could be traced for a degree in length. In the southern hemisphere the conditions for seeing and observing were somewhat better than in Europe. It passed its perihelion on December 18 at less than one-fifth of the Earth's distance, and owing to this tolerably close approach has remained too near the Sun for post-perihelion observation. Owing to a rapid movement northward, however, it may possibly be seen in February, but the brilliancy will only be about one-sixth of that at the discovery. The motion can be represented by a parabola.

The last cometary discovery of the year is due to Mr. Brooks, of Geneva, who, on the morning of November 21, perceived a comet low down in the south, but moving into a more favourable position. The elements show that the perihelion passage had taken place a month before the discovery. The comet was then not well situated for observations in the northern hemisphere. The discoverer described the comet as bright, but European observers generally have found it faint and difficult to follow. Its great northerly declination has been of assistance in securing a good series of observations, and it is still possible to observe it in powerful telescopes. The motion appears to be parabolic, but attention has been called to the fact that the elements closely resemble those of the comet of 1652, as shown below.

	Brooks' Comet (Berberich).	Comet of 1652.
Long. of Perihelion	298 46	300 11
„ Node	86 6	91 33
Inclination	76 15	79 28
Log. least distance from ☉ ...	9·9259	9·9279

The observations of the comet of 1652 are deserving of a new discussion.

To this notice might be added the fact that both Barnard's Comet, discovered in 1884, and that of Brorsen, have passed perihelion within the year without being observed. The former was expected in June, but the maximum theoretical brilliancy was only about twice as great as that at the time when the comet was last observed in 1884. Except it be rediscovered by accident, its chance of future observation is slender. Brorsen's Comet, supposing it to be moving in the orbit in which it was last seen, approached the Sun in August, an unfavourable time of the year for perihelion, since at the time of greatest brilliancy the comet is near the Sun.

W. E. P.

Progress of Meteoric Astronomy in 1895.

January Meteors.—On the evening of 1895 January 1 Mr. Corder, at Bridgwater, saw only 8 or 9 meteors (including 2 or 3 *Quadrantids*) between $6^h\ 15^m$ and $10^h\ 45^m$, but the sky was partly cloudy. At Bristol 5 meteors were recorded during a watch of two hours before $8^h\ 20^m$. At the latter place the sky was pretty clear during most of the time of observation. The expected display of *Quadrantids* failed to present itself but in very meagre form. Two of the meteors, which appeared on January 1, were seen both at Bristol and Bridgwater—at $6^h\ 43^m$ a *Quadrantid* of the 3rd magnitude fell from a height of 58 to 47 miles over N. Wales, and at $7^h\ 24^m$ a slow *Eridanid* of the 2nd magnitude fell from a height of 65 to 50 miles over S. Wales. The radiant of the former was at $233°+56°$, of the latter at $62°-12°$.

April Meteors.—On the nights of April 17, 19, 21, 23, and 24 Mr. Blakeley, at Dewsbury, in watches extending altogether over 10 hours, saw 45 meteors, including 23 *Lyrids*. The radiant seemed at $270°+36°$ on 19th, $274°+36°$ on 21st, and $280°+35°$ on 23rd and 24th. The several positions suggest a rapid displacement to the eastward. Mr. Corder observing on April 19, between 11^h and $15^h\ 15^m$, counted 27 shooting stars, of which 15 were directed from the region of *Lyra*. The most brilliant ones and several others make a definite radiant at the usual position, $274°+34°$, but the rest could not be brought into conformity with this point, some of them being directed from about 8° N. and some 10° E. of it. A few meteors of the April epoch

were also observed by Professor A. S. Herschel at Slough, and by the writer at Bristol. Three of the most brilliant of those recorded were fortunately seen at more than one station, and their heights and radiants were as follows :—

1895.	Time.	Mag.	Height at Beginning.	Height at Ending.	Length of Path.	Radiant Point.
April 14	11 44	1	87 miles	71 miles	107 miles	316° + 31°
19	10 59	1 − ♀	91 ,,	43 ,,	97 ,,	269 + 30
19	11 46	1	77 ,,	70 ,,	40 ,,	300 + 20

The second in the list was a brilliant *Lyrid*, well observed at four stations. It was estimated as 2 × ♃ by Mr. Blakeley at Dewsbury, and as = ♀ by Mr. D. E. Packer at Birmingham.

August Meteors.—Moonlight partly interfered with observation, but otherwise the conditions were favourable. Between August 7 and 11 Mr. Corder noted 134 *Perseids*. Mr. Blakeley recorded 46 during watches on clear nights from August 2 to 14, and at Bristol between August 7 and 11, 29 *Perseids* were mapped. Professor Herschel found the *Perseids* scarce from $10^h\ 50^m$ to 12^h on August 7, for though the sky was cloudless only 4 meteors were seen. On August 11 Professor Herschel watched a clear sky from $9^h\ 50^m$ to 12^h, and recorded 26 paths, the great majority of them being *Perseids*. The following radiants were determined :—

Aug. 2	35° + 55°	16	E. R. Blakeley
7	39 + 53	11	,,
7	40 + 56	...	H. Corder
7	41 + 57	5	W. F. D.
10	45 + 55	17	,,
11	43 + 58	...	A. S. Herschel
11	43½ + 58	...	H. Corder
11	44 + 58	7	W. F. D.
11	45 + 56	13	E. R. Blakeley
14	51 + 58	6	,,
18	51 + 56	...	H. Corder

The easterly motion of the radiant is well indicated from these observations, but the shower was neither a numerous nor a brilliant one. Professor Herschel found the radiant very diffuse on August 11, and Mr. Corder describes it as very scattered and indefinite. Six of the meteors recorded between August 7 and 11 were observed at more than one station, four of them being *Perseids*. The other two were from radiants at 45° + 47° (*α Persei*) and 333° + 36° (*ι Lacertæ*) representing well-defined minor showers of the August period.

October Meteors.—Mr. Blakeley observed 11 *Orionids* between October 16 and 23 from a radiant at $90° + 14°$, and a contemporary shower of unusual activity had its centre east of *α Ceti* at $47° + 4\frac{1}{2}°$ (10 meteors). The latter forms a well shower of slow meteors; it was seen in 1869 by Lieut.-Colonel Tupman on October 14 at $44° + 4°$, by the writer at Bristol, in 1879 on October 20 at $45° + 6°$, and in 1886 on October 22 at $43° + 5°$. On October 16 Mr. Corder registered 6 *Orionids*, and determined the radiant as at $91° + 15°$. The shower could not be well traced, for though the Moon was absent from the sky cloudy weather prevented much observation.

November Meteors.—It was expected that the *Leonid* stream might exhibit increased activity in 1895, as we had arrived comparatively near the time of maximum, but though the sky was attentively watched the results proved the display to have been of an ordinary character, such as that which occurred in 1879 or 1888 when the parent comet (*Tempel I.* 1866) was not very far removed from aphelion. The following is a summary of observations:—

Date. 1895.	Hours of Observation. h m to h m	Duration. h m	Meteors Seen.	Leonids.	Observer.
Nov. 12	14 5 to 16 30	2 25	18	3	Corder
12	15 15 17 0	1 45	7	2	Herschel
13	9 40 13 0	3 20	14	1	Riggenbach
13	10 30 13 0; 14 0 14 20	2 50	...	11	Booth
13	11 0 13 30	2 30	10	2	W. F. D.
13	11 30 15 40	4 10	34	16	Blakeley
13	12 10 15 10	3 0	18	7	Herschel
13	14 0 16 10	2 10	26	11	Corder
14	12 40 14 25	1 45	10	2	Herschel
15	11 45 12 40	55	...	1	Blakeley
16	12 15 13 30	1 15	...	1	"
16	16 15 18 15	2 0	22	12	Corder
17	14 0 17 0	3 0	30	8	"

Radiant Point.

$151° + 23°$	9 meteors	Herschel
$154 + 23$	34 "	Corder
$154 + 24$	11 "	Booth
$150 + 23\frac{1}{2}$	16 "	Blakeley

Very brilliant *Leonids* were seen by Mr. Blakeley on November 13 $13^h\ 50^m$, about $\frac{1}{4} =$ ☽, and on November 16 at $12^h\ 32^m$, about $\frac{1}{2} =$ ☽. The latter was followed in 11 minutes by a very per-

T 2

ceptible detonation. One noteworthy feature of the display in 1895 was its extended duration, for it still maintained a decided activity as late as the morning of the 18th, according to Mr. Corder's observations.

Contemporary with the *Leonids*, the *Taurids* formed the chief display among the many minor showers. Mr. Corder noticed about 20 of them, and found the radiant at $58^\circ + 22\frac{1}{2}^\circ$. Mr. Blakeley also recognised this stream, and placed its radiant at $59^\circ + 22^\circ$. He saw other showers at the same period, among them being radiants at $45^\circ + 21^\circ$ (*Arietids*) and $51^\circ + 44^\circ$ (α *Perseids*). Like the *Taurids* and *Arietids*, the latter furnishes slow meteors. It is a well-marked November shower, and was first seen in 1879 November 12–14 by the writer, when its radiant (D. 767) was placed at $48^\circ + 43^\circ$.

December Meteors.—On December 10 Mr. Corder, watching until midnight, counted 31 meteors. On December 11, between $13^h\ 45^m$ and 18^h he recorded 88, so that they were fairly numerous. He remarks that few of those seen belonged to the companion radiant of the *Geminids*, near β *Geminorum*, at about 119 + 29. Mr. Blakeley, watching on December 12 until 12^h, saw 24 *Geminids* from a radiant at $108^\circ + 33^\circ$. Mr. W. E. Sperra, writing from Randolph, Ohio, U.S.A., says: "An unusual number of bright shooting stars were noticed this morning (December 13) radiating from a point near the zenith, or somewhat south of it." (*Popular Astronomy*, iii. p. 270.)

Fireballs.—On the night of March 10, while observers were watching, in the clear frosty air that prevailed, the varying phases of the total lunar eclipse, two fine meteors burst into view. The first was noted at $14^h\ 27^m$, and appears to have been witnessed by many persons. A comparison of the various descriptions shows that its radiant point was in *Cepheus* at $330^\circ + 59^\circ$, and near that of the detonating fireball of 1894 January 25 (see *Monthly Notices*, vol. lv. p. 238). It descended from a height of 50 miles above Llandilo to a height of 23 miles above a point east of Lundy Island, and traversed a path of 58 miles with a velocity of about 19 miles per second. Its apparent brightness was variously estimated, according to the distance of the observers, as = *Sirius*, = ♃, and = ♀. At Cardiff it was seen as a magnificent fireball falling in the western sky, and leaving a long trail of coloured sparks. The second meteor appeared at $15^h\ 24^m$, and was well observed at London, Reading, and Brighton. Its radiant was in *Draco* at $240^\circ + 63^\circ$, and the meteor seems to have fallen almost vertically towards the Earth's surface. It was 80 miles high when first seen, and 40 miles high when it disappeared. Its position was above the Isle of Wight. These deductions are not quite certain, as the observations are not satisfactorily accordant.

On June 10 a large fireball was seen by Messrs. Booth and Townshend at Leeds, and by Mr. D. E. Packer at Birmingham. At Leeds its brightness was estimated as 5 × ♀, and its diameter

as $30' \times 8'$. At Birmingham it was rated at $4 \times$ ♀. The meteor fell from 58 to 44 miles over the N. of England, and its real length of path was about 89 miles. Its radiant was at $259° - 23°$ between *Scorpio* and *Sagittarius*. This region of the ecliptic furnishes the radiants of many large meteors during the summer months.

On July 7, at 10^h 49^m, a beautiful double-headed fireball was observed from many parts of the country. It moved with extreme slowness, but its path has not been determined with well-assured accuracy, for the meteor appeared in a sky brightly lit with the rays of a full Moon, and few stars were visible by which to fix its apparent course. The radiant point appears to have been at $217° - 6°$, and the meteor fell from a height of 53 to 30 miles, beginning over a point near Bath, and terminating its visible career over Birmingham. It had a length of path of 79 miles, along which it travelled with a velocity of about 9 miles per second. The head of the meteor was formed by a double nucleus, separated by an interval of about 530 yards.

On November 14, at 6^h 30^m, a very interesting, though by no mean brilliant, meteor was seen by Mr. Corder at Bridgwater, and by Messrs. Davis and Saunder at Crowthorne, Berks. It moved with remarkable slowness from a radiant point at $319° - 9°$ near β *Aquarii*, which is a more westerly position than that of any shower ever observed in the month of November. The meteor fell from a height of 49 miles over Ringwood, Hants, to a height of 29 miles over Easton, Wilts, and its Earth point was 8 miles W. of Banbury, Oxon. Its real length of path was 40 miles.

Perhaps the most brilliant fireball of the year appeared on November 22 at 6^h 51^m. At Bristol and other places, where the sky and stars were veiled in cloud, the meteor illuminated the firmament with startling intensity, and many people mistook it for lightning. The observations of its path at the few places where the object was displayed in a clear sky are not sufficiently definite to enable the real path to be determined.

Several very large meteors were casually observed in May, June, and December, and in November an unusual number of these bodies appeared on various dates.

The report for 1894 of the Meteoric Section of the British Astronomical Association was published in 1895 June, and contains a summary of useful facts relating to recent observations. There is a list of 98 radiants determined in 1894, also tables of brilliant meteors and some interesting particulars as to the real paths of a few of these bodies.

In *Astronomische Nachrichten*, No. 3,306, Dr. W. Doberck gives a list of 28 radiants of shooting stars recorded at the Observatory, Hongkong, chiefly in the autumnal months of 1891 and 1892, and the author expresses his intention to continue the work. On one ground, however, we are sorry to take exception to the catalogue of radiants furnished by Dr.

Doberck. A considerable number of the positions are deduced from only two or three meteor paths, and are therefore extremely uncertain. It is most undesirable that radiants of feeble showers (already very numerous, and in many instances doubtful) should be adopted on evidence of such slender character. It seems to us that to fix a radiant with anything like accuracy at least five meteors are necessary, except in special cases.

Among the papers published on meteoric astronomy during the year may be mentioned one in the *Monthly Notices* for December last, giving a summary of observations of the October meteors (*Orionids*) which indicate that the radiant is stationary amongst the stars during the three weeks over which the display extends.

W. F. D.

Total Solar Eclipses.

There have been no total solar eclipses of importance during the last two years, but several reports of the one on 1893 April 15–16 have been published.

M. Deslandres, who was deputed by the Bureau des Longitudes to observe the eclipse, and stationed himself at Fundium on the Salum River, where also was one of the English parties, has published accounts of his results (*Comptes Rendus*, 1893 May 15 and 1895 April 1).

M. Deslandres's attention was specially directed to two points. Firstly, to measure the rate of rotation of the corona; and, secondly, to photograph the ultra-violet region of the corona spectrum. The former was attempted by the method of observing the relative displacement of the green "corona" line—when the spectra of two regions of the corona, at opposite sides of the Sun, were placed in juxtaposition. A grating spectroscope was employed, and from the measurements made during the eclipse the conclusion was arrived at, that the corona partakes of the Sun's rotation. Without in any way impugning the skill of M. Deslandres, it is obvious that such a difficult observation must be repeated before it can be accepted as conclusive. The ultra-violet corona spectrum was attacked in the usual manner with a photographic spectroscope furnished with quartz lenses and an Iceland spar prism. A photograph was obtained showing the continuous corona spectrum and superimposed upon this a number of faint bright lines. Forty of these lines were measured between λ 3090 and λ 3629, the great majority of which do not coincide with the lines of any known element. The intensity of the corona spectrum was found to fall off rapidly in the ultra-violet, as would naturally have been expected. Dr. Schuster showed some time ago that the point of maximum intensity of the corona spectrum, as compared with that of the Sun, is shifted considerably towards the red.

Mr. Schaeberle's report on the result obtained by him at

Mina Bronces, Chili, has been published (*Contributions from the Lick Observatory*, No. 4).

The principal work that Mr. Schaeberle set himself to accomplish was to photograph the corona on a much larger scale than had before been attempted. To this end a Clark objective of 5 in. aperture and 40 ft. focal length was mounted on a fixed pier, and the slide carrying the photographic plate on another pier, a canvas tube which was in actual contact with neither of the piers, extending between lens and plate. The slide carrying the plate was the only moving part, and its motion was so regulated by means of inclined planes as to give it the same velocity and direction as the Sun's focal image during the eclipse. With this instrument some very beautiful photographs were obtained, showing the prominences and lower corona with a definition which leaves little to be desired. Copies of these photographs have been presented to the Society, and one has been included in the list of photographs available for distribution, copies of which can be purchased by Fellows.

Mr. Schaeberle is of opinion that the appearance of the corona at this eclipse is a strong confirmation of his, now well-known, mechanical theory. By this theory the rays and streamers of the corona are explained as being streams of matter ejected from disturbed regions on the Sun's surface, and moving in elliptical streams, one focus of the ellipse being at the Sun's centre.

As regards the English observations, the results obtained are rather in the direction of continuity of record than of actual novelty. As is well known, the eclipse was successfully observed by two parties, the one at Para Curu, Brazil, and the other at Fundium in Africa. A splendid set of photographs was obtained at both stations. The spectroscopic results as yielded by the objective prism and by the slit spectroscopes have been reduced by Professor Lockyer and Captain Hills respectively, whose work has been published by the Royal Society. (*Phil. Trans.* 185, p. 711, and *Proc. Roy. Soc.* 56, p. 20.)

The drawing of the corona, combined from all the photographs, has not yet been published, but the photographs have been examined sufficiently to show that there was no perceptible alteration in the form of the corona as seen at the two stations, *i.e.* at an interval of one and half hours.

Professor Thorpe measured the photometric intensity of the corona, but his results have not yet been published.

This year an important total eclipse occurs on August 9, and it is hoped that well-equipped English parties will proceed to both ends of the line of totality—viz., Norway and Japan. The Eclipse Committee are arranging to send four observers to Japan, who will occupy two stations as widely separated as possible, and four observers to Norway. Besides these there will doubtless be many astronomers who will take advantage of an eclipse visible at such a short distance from England, and should

favourable weather be obtained, there is no doubt that the phenomenon will be better observed than it has ever been hitherto. E. H. H.

Solar Activity in 1895.

The solar activity, so far as it is represented by the numbers and areas of Sun-spots, has continued to decrease throughout the year 1895, as throughout the preceding one. But the decline has been very slow, the Sun showing a considerable number of groups on most days, though there have been no great displays like those of 1893 August and December, or of February and the early summer of 1894. At the Lyons Observatory M. Guillaume recorded only twelve naked-eye spots during the first nine months of the year, as against twenty such in the twelve months preceding.

The chief groups of 1895 were observed in March, the early part of August and of October, and the latter part of December; whilst in the beginning of July, at the end of the first decade of October and of November, and at the end of the first week of December, the spots were very few and small. Still, no day throughout the year was entirely free from spots, the last example of the kind having occurred on 1891 March 28.

The decline in number and area has been much more marked in the southern hemisphere than in the northern, the reverse having been the case in 1894, so that now the spots are on the whole pretty evenly distributed between the two, the balance on the whole being in favour of the North. The same even distribution holds good for faculæ, which, M. Guillaume finds, have diminished in mean area about one-fourth. The decline in the mean latitude of spots has been only small; indeed, M. Guillaume's observations indicate a slight recovery in the northern hemisphere during the first three quarters of the year, though, as Professor Tacchini notes, no spots and few faculæ attain a higher latitude than 30°.

Solar Spectroscopy.

Spectroscopic observations of the Sun during 1895 indicate a general, though very slight, decline in activity as regards the ordinary prominences. Professor Tacchini's results for the first half of the year show a well-marked minimum in January, but after that a relative increase in mean daily numbers.

All the observations agree in showing the northern hemisphere to have been more active than the southern, reversing the order of things prevailing since 1892; this change being brought about by the entire suppression of the southern high latitude zone of activity, which in 1894 completely enveloped the south pole. Another feature in the prominence distribution

clearly brought out by the observations both of Professor Tacchini and the English observers is the sharp limitation of the active prominence forming zones within the parallels $\pm 55°$; prominences in higher latitudes having been quite insignificant in number and in size.

Metallic prominences seem to have been relatively numerous, judging from the observations of Mr. Evershed, who finds about 5 per cent. of the prominences seen by him reversing the sodium and magnesium lines, whilst he only found 1·3 per cent. in 1894, observing in each year about 1,000 prominences altogether. This observer also states that the corona line (λ 5316) has been relatively more frequent in the chromosphere.

Eruptive prominences have been very rarely seen. Professor Hale records one on March 25, $9^h\ 50^m$ to $11^h\ 6^m$ Chicago mean time. This, however, seems to be the only large one seen during the year. Professor Hale was fortunate in obtaining some very fine photographs of the phenomenon by means of his large spectrograph with moving slits, adjusted on the K line. From measurements of his plates he deduces the maximum height of the prominence at 624″.

Publications of the Astrophysical Observatory of Potsdam, vol. x.

The first part of the tenth volume, No. 32, of the *Publications of the Potsdam Observatory* bears an especial interest to solar physicists as containing the last published observations of Professor Spörer, late Chief Observer there. They consist of tables giving the position-angles, heliographic longitudes, longitudes from the central meridian, and heliographic latitudes of groups of Sun-spots, in the form of a ledger for each rotation of the Sun. Descriptions of the groups are added as foot-notes, and the whole embraces a period of nine years, from 1884–1893, which covers roughly the interval between two maxima of spotted area with the included minimum. Two series of charts at the end of the volume illustrate the ledger, one series giving a representation of the entire spot display of the Sun, rotation by rotation; the other showing the distribution of the several groups in heliographic latitudes. The coexistence of two widely separated regions of disturbances is very evidently indicated in the chart for the minimum of 1889–1890. In 1889 the groups are at first clustered closely on the equator, but in the last seven rotations of the year spots appear in very high southern latitudes; and as the equatorial spots disappear, groups in high northern latitudes are also seen. In 1890 and 1891 the equatorial spots become fewer, and are separated by long intervals of time; but the high latitude spots are numerous, and evenly distributed in time in the southern hemisphere, and by 1891 are preponderantly numerous in the high north. In the Introduction, Professor Spörer explains the methods of observation. Weather

permitting, Dr. Lohse each day took photographs, which were utilised, together with Professor Spörer's eye-observations, in obtaining the positions of the spots. The plates were measured until 1891 by Dr. Wilsing, and later by Herr Roller. The advantages of the direct observation methods over the photographic are, according to Professor Spörer: (1) on many days when no exposure can be given direct observation of spots can be made in breaks in the clouds; (2) when the sky is covered with a thin veil or mist only faint pictures of larger spots can be obtained, but telescopic observations at the same time can better identify the spots and allow measures of their places to be taken, and the brief moments of better seeing can be utilised; (3) for small spots, as in the case of stellar plates, an independent check is necessary to prevent the measurement of defects of the plate.

No. 33 is the volume containing the meteorological observations for the years 1888–1893, made under the direction of Professor Kempf.

Helium.

The discovery of the substance giving rise to the bright "helium" line, D_3, of the solar chromosphere and prominences was a sequence of the discovery of argon. Professor Ramsay, in his search for possible sources of argon, had his attention drawn to uraninite by a paper by Dr. W. F. Hillebrand "On the Occurrence of Nitrogen in Uraninite, &c." (*Bull. of the U.S. Geol. Survey*, No. 78, p. 43). The particular mineral employed by Professor Ramsay was clèveite, essentially a uranate of lead, from which he derived—by boiling with weak sulphuric acid—a gas which, when carefully freed from impurities and, so far as possible, from all known gaseous bodies except argon, gave in its spectrum not only the lines of argon but the long sought for D_3 line.

Professor Ramsay describes his discovery in a paper entitled "On a Gas showing the Spectrum of Helium, the Reputed Cause of D_3, one of the lines in the Coronal Spectrum," dated 1895 March 26, and read before the Royal Society. Several vacuum tubes were filled with the gas and their spectrum compared with that of argon thrown simultaneously in the field. "It was at once evident that a new gas was present along with argon. The comparison of the spectra showed a brilliant line in the yellow in the clèveite gas, nearly, *but not quite*, coincident with the sodium line D of the argon tube."

"Mr. Crookes was so kind as to measure the wave-length of this remarkably brilliant yellow line. It is 587·49 millionths of a millimetre, and is exactly coincident with the line D_3 in the solar chromosphere, attributed to the solar element which has been named 'helium.'"

Other sources of helium than clèveite were sought for, and it appears that it is retained by minerals consisting of salts of

uranium, yttrium and thorium. Hitherto the uraninites, clèveite and bröggerite, have been the minerals mostly drawn upon, but monazite, a phosphate of cerium, lanthanum, and thorium, has been suggested by Professor Ramsay as a more economical source.

The laboratory study of the new gas was at once begun and its low density demonstrated. In a paper appearing in the July number of the Journal of the Chemical Society, Professor Ramsay gives its density as 2·13. It is thus the lightest of all known substances after hydrogen. The ratio of its specific heat at constant volume to that at constant pressure is high, viz. 1·632. Its solubility in water is the lowest recorded for any gas, from which it is inferred that the boiling point of liquid helium is very low. Chemically it is, like argon, most inert. "Both resist sparking with oxygen in presence of caustic soda; both are unattacked by red-hot magnesium; and, if we draw the usual inference from the ratio between their specific heats at constant volume and at constant pressure, both are monatomic gases. These properties undoubtedly place them in the same chemical class and differentiate them from all known elements." If argon and helium are both monatomic elements, their atomic weights would be respectively 39·8 and 4·26.

The examination of the spectrum of the new gas realised the expectation, to which the apparent identification of its principal line with D_3 had given rise, that many of the previously unexplained lines of the chromosphere would find in it their counterparts. In a paper appearing in the *Comptes Rendus* of the Paris Academy of Sciences April 16, Professor Clève published Thàlen's measures of six lines, which thus corresponded to six leading chromospheric lines—λ 6677, D_3, 5048, 5016, 4922, 4714. The first of these lines was confirmed by Professor Lockyer in a paper read April 25 before the Royal Society—the first of a series of studies of the spectra of the gases from uraninite. M. Deslandres communicated the wave-lengths of twenty helium lines to the Paris Academy on May 20, and carried the identification of the chromospheric lines still further, amongst them being the line at λ 4472, Lorenzoni's *f*, and later observations have brought out still more correspondencies.

A serious difficulty in the acceptance of the identification of the new gas with solar helium arose when Professors Runge and Paschen found on photographing the spectrum of the former with a concave grating of 6·5 metre radius that the yellow line which it gave was double, and composed of a strong line of wave-length 5875·883 tenthmetres on Rowland's scale, and a much fainter companion, distant from it 0·323 tenthmetres towards the red (*Nature*, 1895 June 6, vol. lii. p. 128). As up to that time the chromospheric line had always been accounted to be really single—though an apparent duplicity, supposed due to the superposition of a telluric line, is on record—it was not until Professor Hale and Dr. Huggins had severally succeeded in

detecting a faint companion to D_3 in the prominence spectrum that the presence of true helium in the clèveite gas became established.

The further study of the spectrum by Professors Runge and Paschen brought out a number of most interesting peculiarities, of which they give an account in a paper appearing in the *Proceedings of the Berlin Academy* of 1895 July 11, and, later, in articles in *Nature* for September 26, and the *Astrophysical Journal* for 1896 January. Since Balmer gave, in 1885, a simple formula for connecting the wave-lengths of the lines of hydrogen, a formula verified in 1890 by Professor J. S. Ames in his careful determination of the wave-lengths of the lines in the ultra violet, many metallic spectra have been found, especially by Professors Kayser and Runge, to be similarly of a strictly rhythmical character, though with these the lines form three series, two of which tend to approach the same limit, whilst the lines of hydrogen form one series alone. Professors Runge and Paschen having determined the wave-lengths of the numerous lines given by the clèveite gas, many of which are close doublets, with the utmost delicacy and refinement within the reach of the most powerful modern spectroscopic appliances, succeeded in resolving the spectrum, so irregular at first sight, into a combination of singularly perfect sequences. "We have investigated," they say, "the spectrum of the gas discovered in the mineral clèveite by Ramsay, and have found it to be most regular. It consists of six series of lines, the intensity of the lines in each series decreasing with decreasing wave-lengths." Of these six series two approach one limit, and two another; the two stronger series of lines being both composed throughout of double lines, the components of which are separated from each other by a constant oscillation frequency, whilst the two weaker series consist of single lines throughout. With each of these pairs of series a third is associated. "We thus get two spectra consisting of three series each, two series ending at the same place, and the third leaping over the first two in large bounds, and ending in the more refrangible part of the spectrum. . . . Each of our two spectra now shows a close analogy to the spectra of the alkalies. We therefore believe the gas in the clèveite to consist of two, and not more than two constituents."

The scale on which the photographs were taken, from which these determinations of wave-length were made, may be inferred from the fact that the average distance apart of the centres of the components of the various doublets was, for the ultra violet, but one-seventh of a tenthmetre; the refinement of the measures from the fact that this distance, as measured, differed from that computed on the assumption of equal differences of oscillation frequency, only by two or three thousandths of a tenthmetre on the average. The great power and precision of the instrument employed have thus enabled a suspicion raised by Professor Ramsay to be set at rest, viz. that the clèveite gas had several

lines in common with argon. These more delicate measures showed that some of the argon lines were, indeed, near some of the helium lines, but were quite distinct from them.

Analogy with the relations which Professors Kayser and Runge have worked out in the spectra of the alkalies has led Professors Runge and Paschen to suggest that the distance apart of the several components of the clèveite pairs may afford an index of the atomic weight of one of the constituents. If so, the atomic weight of the gas in the spectrum of which D_3 occurs will be between 5·2 and 5·7, and it follows that the other constituent which is supposed to exist in clèveite must be considerably lighter.

This view, that the gas from clèveite really consists of a mixture of two gases, of which the one—the heavier constituent presumably—gives a spectrum in which the D_3 line is most conspicuous, and which is therefore the true solar helium, whilst the spectrum of the other is characterised by the green line at λ 5016, appears to be confirmed by the following considerations.

The supposed "lighter constituent," which Dr. Johnstone Stoney suggests should be called "parhelium," appears to be transmitted through a plug of asbestos more rapidly than the true "helium," for after such diffusion D_3 and its associated lines decrease in brightness relatively to λ5016 and its companions. The inference is not, however, beyond objection, for a similar result is obtained by a simple diminution of pressure; and further experiments with larger quantities of the gas are needed. This alteration in the relative brightness of the spectra of the supposed two gases has been noted not only in the regions of the spectrum explored by the eye and the photographic plate, but also in the infra-red. Theory indicated that the initial line of each of what have been called the two principal series should be found in this region, and accordingly exploration with the bolometer revealed two strong lines in the predicted places far below the visible limit of the red end of the spectrum. And under the influence of change of pressure these lines varied relatively to each other, just as the lines of the two spectra in the visible region do.

Of the six strongest lines of the clèveite gas spectrum, three, viz. λ 7066, 5876 (D_3) and 4472, are given the frequency number 100 in Young's table of the chromospheric lines; whilst those at λ 6678, 5016 and 4922 have the numbers respectively 25, 30, and 30. The first three lines belong to the true "helium" spectrum, the last three to that of "parhelium." Both Professor Lockyer and M. Deslandres had independently expressed their opinion that the clèveite gas was not a simple one, but a mixture, from the commencement of their study of it, basing that opinion on the difference in behaviour of the different lines corresponding to it in the chromosphere.

In Nova Aurigæ, the "lighter constituent" was represented by two very strong lines, λ 5016, and 4922, and apparently by a

third, λ 6678; but "true helium," if at all, by only λ 5876 and 4472, both very weak.

On the other hand, a decidedly larger proportion of the lines of "helium" appear to have been recognised in the spectra of nebulæ than of those of "parhelium."

The view, therefore, that the gas obtained from clèveite is really a mixture, of which helium is one constituent, has much in its favour, if it cannot yet be said to be fully established.

The curious, and as yet unexplained, peculiarity of the lines of helium, that like D_3 they are not seen as dark lines in the ordinary solar spectrum, does not hold good for all stellar spectra. A large number of the lines of both spectra have been found by Professor Vogel in *β Lyræ*, and in ten of the principal Orion stars. And besides these, so high a proportion as 25 out of 150 of the brighter first type stars show them, besides 4 stars in which the *Orion* line, λ 4472, was discovered by Dr. Scheiner. This discovery has led Professor Vogel to revise his classification of star-types; and Class I. *b* is now defined as consisting of spectra showing, with the still dominant hydrogen lines, the lines of clèveite gas; whilst Class I. *c* is divided into two subdivisions, according as the bright lines seen are those of hydrogen lines alone, or of hydrogen, helium, and some of the metals.

The *Wolf-Rayet* stars, Vogel's Class II. *b*, have as yet yielded only four of the helium lines; the solar stars, Class II. *a*, and the banded spectra, Classes III. *a* and III. *b*, appear not to show them at all.

The lines of argon have not been observed as yet in any celestial spectrum, but the examination of the gas derived from some meteoric iron from Augusta County, Virginia, has shown Professor Ramsay not only the presence of helium, but of that of argon likewise; indeed, the latter appeared to be much the more abundant.

Heliometer Determinations of the Solar Parallax and Mass of the Moon.

From the report of the Cape Observatory it will be seen that a volume dealing with the heliometer work organised by Dr. Gill, and in great measure carried out by him personally, is nearly completed. Preliminary accounts of some of the results have been published (*e.g.* in the *Monthly Notices* for 1894 April; and in Professor Newcomb's "Astronomical Constants"), and these are sufficient to show the excellence of the work and to intensify the interest with which the publication of the volume is expected. It seems advisable, however, to defer any account of these results until the next report, when the work will have appeared in its complete form.

Astronomical Papers of the American Ephemeris.

The papers of this important series published during the past year are Newcomb's *Tables of the Sun*, *Tables of Mercury*, and *Tables of Venus* (vol. vi. parts 1, 2, and 3), and Hill's *Tables of Jupiter* and *Tables of Saturn* (vol. vii. parts 1 and 2). As the publication of the solar and planetary tables (the end and aim of the researches on which Professor Newcomb has been engaged for many years) has so far advanced, it seems a fitting opportunity to review, as briefly as possible, the inception and progress of the work now approaching completion.

Fortunately for this purpose, Professor Newcomb has recently published a monograph, "The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy," which gives a summary of the work on which he has been engaged for the last eighteen years, and indicates the more important of the results to which he has been led.

It must be premised, however, that the work of the revision of the theories, and construction of the tables, of *Jupiter* and *Saturn*, was assigned to Mr. G. W. Hill. The result of this division of labour has been the introduction of a certain amount of diversity in the data and methods employed, which will necessitate a separate reference to Mr. Hill's work later on.

"The diversity in the adopted values of the elements and constants of astronomy is productive of inconvenience to all who are engaged in investigations based upon these quantities, and injurious to the precision and symmetry of much of our astronomical work." These words give the keynote to Professor Newcomb's endeavours to derive improved values of the fundamental elements, and to embody them in new tables of the celestial motions. The necessary conditions laid down by Professor Newcomb are that such tables shall be founded upon uniform elements and data, and that the results of employing the adopted elements shall be carried out with all necessary precision. Granting these premises, it is not difficult to show that even Le Verrier's work—great as it was in relation to the astronomy of quarter of a century ago—leaves much to be desired in the way of attainment of uniformity in adopted astronomical data. So that his work, though making a greater epoch in astronomy than that of any of his immediate successors can be expected to make, does not wholly supply the wants of science in the immediate future. Professor Newcomb points out that similar objections apply to his own table of *Uranus* and *Neptune*.

Guided by these considerations, Professor Newcomb resolved to devote all the available force at his command to this very important undertaking. The preliminary researches are published in five volumes of the series of papers. The solar tables, as mentioned above, form vol. vi. part 1.

The first step in such a work obviously consists in the reduc-

tion of observed positions of the Sun and planets to a uniform equinox and system of declinations. This was effected by means of the Catalogue of 1098 Standard Clock and Zodiacal Stars (vol. i. part 4), in which the right ascensions are those of Newcomb's fundamental equatorial stars, and the declinations those of Boss. These are, however, eventually corrected by means of the observations of the Sun and planets. The tabular elements adopted for correction were those of Le Verrier's tables. It was however, found necessary to apply corrections to the geocentric places deduced from these tables to reduce them to a uniform system of masses. In the determination of corrected solar elements it was considered advisable, in view of the systematic errors affecting the observations of the Sun, to combine them with observations of the inner planets, when these were favourably placed for the purpose. The results of transits over the Sun's disc also enter largely into the finally adopted corrections in the case of *Mercury* and *Venus*. The transits of *Mercury* are discussed in vol. i. part 6 of these papers; those of *Venus*, in 1761 and 1769, in vol. ii. part 5. For the results of the transits of *Venus* in 1874 and 1882 Professor Newcomb depends entirely on the heliometer measures and photographs of the German and American expeditions.

Professor Newcomb's attention was attracted to a singular discordance among the residuals of the normal equations for *Mars* for different periods. On examining into the matter, he was led to the conclusion that the theoretical value of the coefficient of a certain long period term in the mean motion of *Mars*, depending on the action of the Earth, and having for argument $15g' - 8g$, was not determined with sufficient accuracy. It was decided, therefore, to make an approximate empirical correction to the theory, as the work on which Professor Newcomb was engaged could not wait for a new determination of the coefficient referred to. M. Leveau has, however, recomputed the coefficient of the inequality in question (*Bulletin Astronomique*, tome xii. pp. 507–515), and finds an exact accordance with Le Verrier's result. It appears, therefore, that the anomalies, to which Professor Newcomb has drawn attention, must be referred to some other cause.

The masses of the planets having been determined by methods independent of the secular variations, and the resulting computed secular variations having been compared with the values deduced from observation, some considerable discordances (besides the well-known motion of the perihelion of *Mercury*) were brought to light. Various hypotheses, referring to the action of unknown masses or arrangements of matter, are discussed by Professor Newcomb with regard to their adequacy to account for these discordances. The hypothesis most favoured by him is that propounded by Professor Hall in the *Astronomical Journal*, vol. xiv. p. 7, to the effect that the gravitation of the Sun and planets is not exactly as the inverse square of the distance.

Assuming that the exponent of the distance is 2·0000001612, it is found that the motion of the perihelia of the four inner planets can be well represented. In the result, Professor Newcomb decided to increase the theoretical motion of each perihelion by the same fraction of its mean motion (*i.e.* ·0000000806), a course which will represent the observations, without committing him to any assumption as to the cause (though it agrees with the result of Hall's hypothesis), and to adopt for the elements what he calls "compromise" values between those reached by the solution of the equations of condition, and those which would exist if there is abnormal action of the kind suggested. By this procedure the outstanding discordances are reduced within narrow limits.

An independent test of Hall's hypothesis is, as Professor Newcomb points out, very desirable. The most favourable case, for such a purpose, is obviously that of the Moon, where the motion of the perigee would be accelerated, under the assumed conditions, by about 140″ per century. The theoretical motion has not yet, however, been determined with sufficient accuracy to decide the point. And, as a matter of fact, the observed motion of the perigee, and of the node, when compared with Hansen's theory, give results, the one favourable, the other unfavourable, to the hypothesis in question.

An important part of Professor Newcomb's plan consisted in the adoption of uniform and consistent values of the fundamental constants of astronomy. In the monograph on "Elements and Astronomical Constants," referred to above, these subjects are fully discussed. In speaking of the constant of precession, Professor Newcomb is careful to point out the important bearing on the subject of the now generally recognised difference of "personal equation" in the observations of the right ascensions of faint stars compared with those of bright stars. The constant of precession not being so closely connected with other constants that a small error in its determination will seriously affect general conclusions, being nearly eliminated through the proper motions of the stars, or the motions of the planets in longitude, Professor Newcomb merely combines some of what he considers to be the best determinations. Of these, the one he considers entitled to most weight is L. Struve's "Bestimmung der Constante der Präcession." The value of the annual general precession in longitude for the epoch 1850, to which he is thus led, is 50″·2371.

The mean value of the constant of nutation, which Professor Newcomb adopts, is 9″·214 for 1850.

The doctrine of the interdependence of the constant of aberration and that of solar parallax through the relation that the aberration is equal to the quotient of the velocity of the Earth in its orbit by the velocity of light is accepted by Professor Newcomb: "Its simplicity and its general accord with all optical phenomena are such that it seems to me it should be accepted, in the absence of evidence against it." His "compromise" value

for the solar parallax being $8''.790$, the corresponding value of the constant of aberration is $20''.501$.

The value of the principal coefficient of the lunar inequality which Professor Newcomb deduces from observation is $6''.465$. The observations made use of for this purpose are (1) all the observations of the Sun's right ascension from early in the century to 1864; and (2) the heliometer observations of Victoria made in 1889 on Gill's plan, and reduced by him. It was found that the observations of the Sun made after 1864 gave, by comparison with the published ephemerides, inadmissible corrections to the coefficients; thus giving rise to the suspicion that in interpolating the places of the Sun, during at least some years after 1864, the inequality in question was rounded off to the extent of several hundredths of a second. The results were therefore omitted. The value of this coefficient, adopted in the solar tables, is $6''.454$.

The elements and constants thus determined by Professor Newcomb are used in the construction of his tables of the Sun, tables of *Mercury*, and tables of *Venus*. The periodic perturbations of longitude and radius vector are deduced from those given in vol. iii. part 5 of the series of papers; those of latitude are derived from the data of Le Verrier's tables. The perturbations given in vol. iii. part 5 were computed by adopting the development of the disturbing forces by means of the tables and formulæ of part 1 of the same volume. The perturbations themselves were then derived by a method substantially identical with that employed by Professor Newcomb in his theory of *Uranus*, published in 1873, in which the perturbations of the radius vector are first obtained. The tabulated quantities are the perturbations of the co-ordinates—a course preferable, in Professor Newcomb's view, to the tabulation of the perturbations of the mean anomaly, as in Hansen's method. The development of the perturbative function, as given in vol. iii. part 1, is a modification of Hansen's, and consists essentially of the analytic formulæ by which the development in terms of the eccentric anomaly is symbolically expressed as a function of the elements of the two planets. The transformation from eccentric to mean anomaly is then effected by means of the Besselian functions. It may be mentioned that in the course of this portion of the work Le Verrier's results were reduced so as to depend upon the mean anomalies, for the purpose of comparison. It was found that the agreement of the results was such as to place their accuracy beyond reasonable doubt.

The long period and secular terms of the perturbations are developed in vol. v. part 4 of the papers.

In the construction of the tables of the Sun, of *Mercury*, and of *Venus*, the arguments which are uniformly varying functions of the time are expressed so as to increase by a unit for each mean solar day. The fundamental argument, on which the elliptic terms and the perturbations depend, is the mean anomaly of the Earth, of *Mercury*, or of *Venus*, expressed in the same

unit. By an artifice familiar to those who are in the habit of using astronomical tables, one of the arguments in each table of double entry is made constant throughout an entire revolution. In fact, in all respects, so far as can be judged from an as yet necessarily imperfect acquaintance with the tables, they appear to have been constructed with great skill and care, so as to ensure ease and convenience in their application to actual computations.

Hill's theory of *Jupiter* and *Saturn* forms vol. iv. of the series of papers. This work was originally undertaken by Mr. Hill several years ago. The long interval which occurred between the publication of Le Verrier's theory of *Mars* and the appearance of anything from him on *Jupiter* and *Saturn* was the occasion of his first taking the matter up. As there was no desire to lose time by forming a special method of treatment, it was decided to employ the method of Hansen, with such slight modifications as might be suggested in the course of the work. The presence of the great inequalities renders this method a very suitable one for the purpose. It seemed necessary, however, to Mr. Hill to have a single independent variable for the whole work, in place of the two independent variables, one for the co-ordinates of *Jupiter*, and another for those of *Saturn*, which would be necessary if Hansen's use of the eccentric anomaly were adhered to. Therefore, the final form adopted for all the periodic series involved in the development of the disturbing forces was in terms of the mean anomalies, so that the time is always the independent variable. Only slight changes were necessary in Hansen's formulæ to render them applicable to this modification. For comparison with Le Verrier, in a few particulars, Mr. Hill has reduced Le Verrier's algebraically-determined coefficient of the great inequality of *Saturn* to Hansen's form, and to Bessel's value of the mass of *Jupiter*, and the result comes out $36''\cdot95$ larger than the value obtained by Mr. Hill. In the case of *Jupiter*, although Le Verrier's coefficients correspond to the mass of *Saturn* $1/3529\cdot6$, whilst Hill's correspond to the mass $1/3501\cdot6$, still it is found, for the more important terms, that the former are quite as large as the latter. "This, perhaps, explains why Le Verrier's discussion led him to the too small mass of *Saturn*."

The tables of *Jupiter* and of *Saturn* are founded on the theory thus developed; definitive elements being deduced in each case from the discussion of a long series of observations. The slight want of uniformity between the data of these tables and those of the four inner planets, to which reference has already been made, arises from the fact that it has not been possible to await the final determinations of the constants before proceeding with their construction. It should be noted, therefore, that in the tables of *Jupiter* and *Saturn* the longitudes are not referred rigorously to the adopted equinox, and that the masses of *Uranus* and *Neptune*, used in the construction of the tables, are not those finally adopted.

In the construction of the tables, the form so familiar to

astronomical computers who are accustomed to use Hansen's *Tables de la Lune* has been followed. Mr. Hill has, with much skill, introduced one or two devices for the purpose of increasing the accuracy of the results, or of lessening the labour of calculation, which computers will appreciate. As an instance, we may take the procedure adopted in tabulating certain of the perturbations of the mean anomaly and radius vector of *Jupiter*. In this case a difficulty is met with which arises from the decimal scale of notation. We have the choice between having a certain degree of accuracy or one ten times as great; whereas the degree of accuracy desired lies midway between the two. Under these circumstances Mr. Hill tabulates, not the quantity finally required, but a quantity three times as great, which will merely add to the labour of the computer a single division to be performed on the sum of the perturbations thus multiplied. It will be remembered that a similar device was adopted by Le Verrier in his theories of *Jupiter* and *Saturn*, where the perturbations of double the semi-axis major are the quantities tabulated.

In his Presidential Address on presenting the Gold Medal to Professor Newcomb (*Monthly Notices*, vol. xxxiv. p. 227) Professor Cayley says: "I cannot help thinking that there should be some Confederation of Observatories, or Central Calculating Board, for publishing the lunar and planetary observations, &c., reduced to a concordant system. It seems hard upon the maker of a set of planetary tables that he should not at least have, ready to hand for comparison with his theory, a single and entire series of the observations of the planet." These words are as applicable today as they were twenty-two years ago, and come home with peculiar force to us when we consider the enormous amount of labour imposed upon Professor Newcomb in consequence of the existing diversity in the use of astronomical constants, places of fundamental stars, &c., as adopted at different observatories. Perhaps the publication of Professor Newcomb's work will do something to bring about a more satisfactory state of things. Meanwhile it will be the hope of all astronomers that Professor Newcomb will be able to continue his self-imposed labours, and bring to a successful conclusion his programme of the publication of a series of tables "intended to include the eight major planets of the solar system, and possibly the Moon and satellites."

A. M. W. D.

Star Catalogues.

The *Cape Catalogue* of 1713 stars for the equinox 1885·0, from observations made in the years 1879–1885, was published in 1894, but received too late for a notice of it to appear in the report of the Council last year. The stars observed are mainly fundamental stars and southern circumpolars. About 40 per cent. have ten or more observations. The clock stars employed

are those of the *Fundamental Catalog für die Zonen Beobachtungen am Nördlichen Himmel* between the limits $+10°$ and $-10°$ of declination. The right ascensions of clock stars were only included as determinations when at least five observations were made on the same night. A reversing eyepiece was used to eliminate any difference of personality for quick and slow-moving stars. About 500 stars in this Catalogue are contained in the Greenwich Ten-Year Catalogue for 1880. The differences of right ascension, Greenwich—Cape, expressed in equatorial time, are as follows:—

h h	s	h h	s
0–3	−0·011	12–15	+0·000
3–6	−0·016	15–18	−0·014
6–9	−0·014	18–21	−0·009
9–12	−0·010	21–24	−0·002

At the Cape there is practically no discordance between the reflexion and direct observations of zenith distance, but a horizontal flexure of $-0''\cdot46$ was indicated by observations on the collimators from 1879–1885. This is the converse of what is found at Greenwich, where there is a considerable discordance between the reflexion and direct observations, but only a small (not more than $0''\cdot2$) horizontal flexure. In the formation of this Catalogue Dr. Gill decided to apply a correction of $-0''\cdot46 \sin \zeta$ to the direct observations, and to disregard entirely the discordance between the direct and reflexion observations caused by the introduction of this correction, considering the reflexion observation as entirely responsible for the difference. Accordingly, direct observations only were used, a correction $-0''\cdot46 \sin \zeta$ was applied to them, Bessel's refractions of the *Tabulæ Regiomontanæ* were used unaltered, and the latitude taken as $-33° \; 56' \; 3''\cdot35$. From a comparison of the Greenwich circumpolars, the Cape circumpolars, and the Greenwich and Cape observations of the same stars, Dr. Gill deduces corrections to the colatitudes and the refractions. From these are deduced corrections applicable to the Greenwich Ten-Year Catalogue and to the Cape Catalogue, the corrections to the latter being given definitively in a table at the end of the introduction. Since the Cape Catalogue was published M. Nyrén has published a Catalogue of fundamental declinations, and if weight is to be attached to the close agreement between this and the Ten-Year Catalogue, it would seem that the corrections to the Cape Catalogue should be increased. The following table is a rough comparison of the Cape Catalogue with M. Nyrén's, given along with Dr. Gill's comparison of the Ten-Year and the Cape:—

Mean N.P.D.	Nyrén—Cape.	Greenwich—Cape.
° ′	″	″
47 30	+0·55	+0·73
52 30	+0·39	+0·16
57 30	+0·09	−0·09
62 30	+0·06	−0·01
67 30	+0·15	+0·24
72 30	+0·11	+0·04
77 30	+0·12	+0·20
82 30	+0·46	+0·37
87 30	+0·27	+0·07
92 30	+0·39	+0·20
97 30	+0·24	+0·31
102 30	+0·25	+0·56
107 30	+0·01	+0·43
112 30	+0·23	+0·57

Reference numbers are given for all the stars to the catalogues of Bradley or Lacaille, Piazzi and the British Association Catalogue, and to the Southern Catalogues. Declinations are used instead of North Polar Distances more commonly found in English Catalogues. No correction is applied for proper motion from the epoch of the observation to the epoch of the Catalogue. In an appendix is given a Catalogue of 104 circumpolar stars from observations extending from 1881–1888, and in a second appendix are given the daily results reduced to 1885–0 of meridian observations of β and α and α_2 *Centauri*.

Another zone (20°−25° N. Decl.) of the Catalogue of the *Astronomische Gesellschaft* has been published during the year. The observations were made at Berlin by Dr. Becker in the years 1879–83. The Catalogue is a large and valuable one, containing 9208 stars, with a mean number of observations of 2·7 per star. The mean error of a single observation, deduced from the observations themselves, is $\pm 0^s \cdot 030$ and $\pm 0'' \cdot 44$, and comparisons with Romberg's and the Greenwich Ten-Year Catalogue give results not much larger. Comparisons are given with Struve's "Positiones Mediæ," the Pulkowa Catalogue of 1855, Yarnall's Catalogue, the Second Armagh Catalogue, the Glasgow Catalogues, Romberg's Catalogue, the Greenwich Ten-Year, and the second Munich Catalogue (Bauschinger). Of the 9208 stars, 605 have determinable proper motions, which are given in a table along with the authorities for them; 281 of these are newly determined by comparison of the Berlin places with those other Catalogues, the proper motion obtained from each Catalogue being given separately, along with the number of observations, and the difference of epoch from the Berlin Catalogue. A list

is also given of stars whose places appear to be considerably in error in the older Catalogues.

A Catalogue of declinations and proper motions of 54 stars for use in the determination of the variation of latitude at New York has been compiled by Dr. Davis from all available Catalogues. The places of the stars have been brought up to 1875·0, and in the deduction of the proper motions systematic corrections have been applied to the different Catalogues to reduce them to the system of the *Fundamental-Catalog* of the *Astronomische Gesellschaft.* Altogether, 130 Catalogues from Bradley to the present time have been used, and no time or trouble has been spared in the attempt to obtain the declinations of these stars as exactly as possible.

F. W. D.

Double Stars.

The work in connection with double stars does not appear to show any falling off. As in the Report of last year, it is here treated of under the two heads—observation and calculation.

Observation.—The measures published in the year 1895 are:—

Memoirs Royal Astronomical Society, vol. li.

(*a*) A set of measures of 100 well selected stars, made with a 6-inch refractor during the years 1892–94 by W. H. Maw.
(*b*) Measurements of 70 stars, made with an 8¼-inch refractor at the Temple Observatory, Rugby, 1890–95, by G. M. Seabroke.

Mesures Micrométriques d'étoiles doubles faites à St-Petersbourg et à Domkino.—A separate publication, forming the third series of measures published by Professor Glasenapp, of the St. Petersburg University. They include measures made in 1882–89 with a 4-inch refractor, in 1889 with a 6-inch, and in 1894 with a 9½-inch refractor. Altogether there are about 600 stars measured. Naturally, the earlier measures are of wide pairs.

Astronomische Nachrichten 3300.—Measures of 54 double stars made at the Königliche Sternwarte zu Berlin, in the years 1892–3–4, by Professor Knorre, with a Wellmann double-image micrometer attached to a 9-inch refractor.

Ibid 3303.—A set of measures of southern doubles made in 1894 at Sydney, New South Wales, by Mr. Sellors, with a 11·5-inch refractor.

Monthly Notices, Royal Astronomical Society, 1895 March.

(*a*) Measures of 12 southern doubles made by Mr. John Tebbutt with an 8-inch refractor at Windsor, New South Wales.
(*b*) A list of 28 probably new southern doubles by Mr. R. T. Innes.

Bulletin Astronomique, 1895 July.—Measures of 256 double stars made at the Paris Observatory, in the years 1890–94, with a 12-inch refractor by M. Bigourdan. These embrace 150 Σ stars, 76 OΣ stars, and 30 others.

Astronomical Journal, 359.—Measures of 34 double stars made with the 15½-inch refractor of the Washburn Observatory in 1895, by Dr. T. J. J. See.

Calculation.—An unusual number of orbits of binary stars has been published during the year; they are, however, mostly re-determinations of previously known elements.

Star's Name.	Period (Years).	a ″	e	Reference.
β 989, κ Pegasi	11·4	0·42	·49	*A.N.* 3285
OΣ 535, δ Equulei	11·5	4·45	·14	*A.N.* 3290
ζ Sagittarii	18·9	0·67	·279	*A.J.* 355
β 101, 9 Argûs	22·0	0·65	·70	*A.N.* 3297
Σ 2084, ζ Herculis	35·0	1·43	·497	*A.J.* 357
β 151, β Delphini	27·7	0·67	·373	*A.J.* 357
Σ 2173	46·0	1·14	·20	*A.N.* 3311
Σ 1523, ξ Ursæ Maj.	60·0	2·51	·397	*A.N.* 3323
OΣ 285	76·7	0·40	·470	*A.J.* 356
Σ 3062	104·6	1·37	·450	*A.N.* 3292
Σ 1356, ω Leonis	116·2	0·88	·537	*A.N.* 3311
Σ 2729, 4 Aquarii	126·7	0·70	·543	*A.J.* 341
Σ 1879	146·9	0·92	·58	*M.N.* 1891 Nov.
γ Coronæ Australis	152·7	2·45	·420	*A.N.* 3327
Σ 1536, ι Leonis	178·6	2·48	·76	*M.N.* 1895 June
Σ 1216	174·7	0·64	·43	*A.N.* 3283
Σ 1670, γ Virginis	194·0	3·99	·897	*A.J.* 352
Σ 60, η Cassiopeiæ	195·8	8·21	·514	*A.J.* 355
Σ 1938, μ Boötis	219·4	1·27	·537	*A.N.* 3309

A.N. = *Astronomische Nachrichten*. *A.J.* = *Astronomical Journal*.

M.N. = *Monthly Notices*, R.A.S.

Besides the calculation of orbits the work done includes the following:—

Astronomische Nachrichten, 3313.—Mr. Roberts investigates the mass, proper motion, and position of *α Centauri* from the Cape meridian observations.

The Observatory, 1895 February.—Mr. Lewis has a note on the motion of Σ 1306, *σ Ursæ Maj.* He shows that the motion is rectilinear.

The Observatory, 1895 March.—Mr. Lewis investigates the motion of the three stars forming the group Σ 1516.

Contributions from the Observatory of Columbia College, No. 6.—Professor Hermann Davis determines the parallax of the binary star Σ 60, *η Cassiopeiæ* from Rutherfurd photographic plates, $\pi = + 0''\cdot443 \pm 0''\cdot043$. T. L.

Schur's Heliometric Triangulation of Præsepe.

The fourth part of the Göttingen Observatory publications is devoted to measures of position of the brighter stars in the cluster *Præsepe*; and principally to a heliometric triangulation of forty-five stars carried out during the years 1889 to 1893. The Göttingen heliometer (6-inch aperture, by Repsold) was erected in 1888; and after being adjusted was immediately devoted by Dr. Schur, the Director of the Observatory, to a piece of work projected twenty years before. On the occasion of the transit of *Venus* in 1874, Dr. Schur had resolved that if ever he possessed a fine heliometer he would undertake the triangulation of *Præsepe* at once; and this resolution remained unshaken by the advances made in photography. The number of distances measured between different pairs of the 45 stars selected was 123; and the resulting equations are reduced to 74 normal equations with 74 unknowns. After some consideration a direct solution of these equations was undertaken, and completed after ten weeks' incessant labour. More than half a million figures were required, and the author justly claims that this piece of work ranks among the most laborious of the kind ever accomplished. The result, as shown by the residuals, is eminently satisfactory. But a study of the systematic errors leads to a new arrangement of the material, giving 68 normal equations with 68 unknowns; and this new task was also undertaken and completed; and the places for these 45 stars are thus obtained with great accuracy for epoch 1890.

Some thirty years before, Dr. F. A. T. Winnecke had made a careful series of measures of these 45 stars with the micrometer of the Bonn heliometer, though the observations were never completely reduced. The reduction is carried out by Dr. Schur in the second part of the volume just published, with every attention to the systematic errors. And, finally, in the third part of the volume, the two series of places are compared, and proper motions during the thirty years' interval are deduced, which must be of great accuracy, considering the immense care and labour bestowed upon both sets of observations. While most of the stars seem to have sensibly the same proper motion, there are six exceptions, which apparently do not belong to the cluster. It will be remembered that Dr. Elkin found similar outstanding stars in the case of the Pleiades.

The Astrographic Chart.

The *troisième fascicule* of the second volume of the *Bulletin* appeared under date 1895 March. In it M. Tisserand gives a general review of the situation in a preface, and, at the suggestion of Dr. Gill, proposes a meeting of the Committee in 1896 May. This meeting has now been definitely fixed for May 11 and succeeding days ; and it is hoped that several questions of great importance may then be settled.

The general situation, as reviewed by M. Tisserand and as given in detail in an appendix to the *fascicule*, is not much changed since last year's report of the Council. The completion of the catalogue plates may be counted on at an early date ; for instance, at the Cape Observatory all but fifteen have been obtained. The chart plates are, however, much behind, and at some observatories have not even been commenced. No reproductions of the plates have been published, though the Astronomer Royal has exhibited some specimens to this Society.

As regards the measurement of the plates, differences in methods adopted at different observatories will doubtless form a subject of discussion at the next meeting of the Committee, and comment may thus be profitably deferred until the next report. At Greenwich and Oxford the rectilinear method of reduction has been given a thorough trial, with satisfactory results. At Paris it is preferred to work with R.A. and Decl. throughout.

In an interesting paper M. Trépied discusses photographic magnitudes obtained from star-images, and comes to the conclusion that a test-plate must be taken on each evening and used in the reduction of the measures. He does not, however, consider the question how far the conditions change during the same evening.

Astronomical Photography.

The progress of astronomical photography during the past year has been marked by the improvement and increased use of appliances and modes of working already known, rather than by the production of any very novel features. Amongst the chief new instruments brought into use are the "Oblique Cassegrain" telescope of Dr. Common, and the Cassegrain reflector of 250 feet focal length, constructed by Professor J. M. Schaeberle, at the Lick Observatory. For this latter instrument Professor Schaeberle employed a silvered-glass mirror 18 inches in diameter and 12 feet focal length, which he constructed some years ago, and which it had been intended to mount as a Newtonian. This mirror Professor Schaeberle perforated and fitted up with a convex mirror on the Cassegrain system, and, after experimenting on mirrors of different convexities, finally adopted one giving

an equivalent focal length of 250 feet. With this telescope some very successful photographs of *Saturn* have been obtained, the diameter of the outer ring being 0·6 inches. The instrument is especially intended for planetary photography. At the Observatory of Yale College, also, a multiple camera for obtaining photographic records of meteors has been erected, this consisting of a massive equatorial mounting of the English type carrying six photographic cameras, these cameras being capable of collectively covering a large area of sky.

The value of photographic records in connection with variable star observations has been shown by the discovery of a large number of variables resulting from the examination, at Harvard College Observatory, of the photographs of stellar spectra made in connection with the work of the Henry Draper Memorial, and of the Harvard chart plates. The success in the photography of nebulæ and star groups obtained by Professor Barnard with the projecting lens of a small optical lantern, this lens being but 1½ inch in diameter and about 4½ inches in focal length, has shown how much can be done in competent hands by very moderate optical appliances. Dr. Sheldon has also been successfully working in the same direction, while Mr. Joseph Lunt has obtained some very satisfactory photographs with an equatorial telescope without clockwork, and guided entirely by hand, exposures up to 30 minutes being given. Dr. Roberts's photographic work during the past year is detailed as usual in the report of his Observatory.

An important contribution to the literature of astronomical photography has been made during the past year by Professor W. H. Pickering. This memoir, entitled *Investigations in Astronomical Photography*, forms Part I., vol. xxxii. of the "Annals" of the Harvard College Observatory, and deals with the photographic work carried out under the direction of the author at above-named observatory during the years 1887–1891. Treating first of fundamental principles, Professor Pickering discusses in detail the effects of variations in aperture and focal length of the telescopes employed, and describes modes of enlargement of the negatives, their reproduction on paper, the qualities of plates, methods of development, and other matters relating to the practical work of astronomical photography. A second section deals with the great nebula of *Orion* and results deduced from various photographs made of it, while a third section is devoted to the discussion of visual and photographic observations of the lunar surface. As regards telescopes, Professor Pickering expresses a preference for refractors in all cases where photographs have to be made for purposes of measurement; while he regards a reflector of long focus as especially suitable for photographing very faint stars, and a reflector of short focus as particularly adapted for dealing with nebulæ. Professor Pickering's experience favours the use of an enlarging lens in cases where planets or close double stars have to be photographed, an ordinary

positive eye-piece being, on the whole, found the best form of such lens. At Harvard Observatory the diameter in declination of the smallest star-images under the most favourable circumstances is $1''\cdot5$ when no enlarging lens is used, while with an enlarging lens discs as small as $0''\cdot5$ have been obtained, and images $0''\cdot7$ in diameter are frequently secured under good conditions.

The question of how astronomical photographs can best be copied for distribution is one of rapidly growing importance, and much remains to be done before it can be regarded as satisfactorily solved. Up to the present transparencies on glass have proved the most faithful reproductions, but these are inconvenient for transport and are open to other objections. Paper prints are, of course, by far the most convenient form of copies, and for popular illustrations of celestial features they serve perfectly. In a recent paper, Professor H. H. Turner (see *Monthly Notices*, p. 26, ante) has shown how paper prints may also be employed in cases where accurate measurements of stellar positions have to be made. When produced carefully, and by suitable processes, paper prints of astronomical photographs can undoubtedly be usefully employed for other branches of research, but all prints so used should be subjected to very careful comparison with the originals from which they are made. This is particularly the case with prints from photographs of comets or nebulæ, in which many appearances of false nebulosity may be caused by defective printing. Processes in which the image is developed on the paper —as in the platinotype process—are perhaps more liable to defects of this kind than "printing out" processes, but in any case very great care and experience on the part of the operator are necessary to ensure satisfactory and trustworthy results.

One of the most important features connected with the development of astronomical photography is the facility it affords for obtaining increased assistance in the carrying out of various lines of research. There are at the present time large numbers of more or less skilled astronomers, both professional and amateur, who are prevented from carrying out work of real scientific value owing to the want of proper instrumental means or other causes. By the proper utilisation, however, of astronomical photographs the abilities of this army of workers can be turned to account. Already the authorities of the Lick Observatory have offered to place copies of their lunar photographs at the disposal of those who will undertake to systematically examine them and discuss the features they record, while more recently Professor E. C. Pickering has similarly offered to supply copies of the Harvard photographs to those who will properly use them for variable star investigations. Dr. Roberts, too, has shown how useful work can be done by comparing the more recent photographs of nebulæ and those taken some six or seven years ago. To fully utilise the data recorded in the enormous store of astronomical photographs now being accumulated at

public and private observatories in all parts of the world some more organised system of examination than at present exists appears to be eminently desirable. It is not sufficient that the photographs of a particular class taken at one Observatory should be compared *inter se*: they should be compared also with other photographs of a similar class taken at other observatories with different instruments, and probably also with different plates and using different methods of development. It is only in this way that errors due to imperfections in the photographic processes can be properly eliminated, while such a comparison, if performed by competent examiners, and the results reported to the observatories supplying the photographs examined, would undoubtedly do much to improve future photographic work.

It was with a view of promoting the proper utilisation of astronomical photographs that the Royal Astronomical Society a year ago decided upon the publication of copies of photographs in their possession in a form which would render them available for the use of the Fellows at a moderate cost. During the current session a start has been made with such publication, and already copies of thirty photographs are available for issue in the form of prints (made by two processes—aristotype and platinotype) or as lantern slides. The demand which has arisen for the copies so published encourages the Council to believe that it will be possible to very greatly increase the number of photographs of which copies may be made available. Such extension of the scheme of publication must, however, necessarily be gradual, in the first place because the funds available for such work are limited, and secondly, because it is evidently undesirable to accumulate a stock of photographs for which there is no demand, a result which can only be avoided by experience of the requirements of the Fellows. It is hoped that as this experience is acquired, and as the work which the Society is doing in this direction becomes better known, it may be possible to publish extensive series of astronomical photographs, collated from a great variety of sources, bearing upon definite lines of research, and that in this way there may be rendered available for thorough scientific examination and discussion an enormous mass of data which is at present almost entirely unutilised.

The Astrophysical Journal.

A step which promises to be one of great importance for the development of the astrophysical side of astronomy was taken a little over a year ago, in the starting of *The Astrophysical Journal: an International Review of Spectroscopy and Astronomical Physics.* Professor G. E. Hale and other leading American astronomers had long been contemplating the desirability of devoting an entire journal to astrophysics, and so supplying one single standard means of publication for all papers bearing upon

the subjects embraced under that head, whether they approach them from the astronomical or the physical side. A beginning had been made three years earlier by the transformation of the *Sidereal Messenger* into *Astronomy and Astrophysics*, the last-named journal being divided into two distinct sections under separate boards of editors : the section of general astronomy and that of astrophysics. But having consulted many of the leading European astronomers, and having been assured of their co-operation and support, Professor Hale and his coadjutors found they were now able to give that international character to their undertaking which was essential to its full success. They therefore in 1895 January brought out the first number of a journal under the above title, and devoted entirely to astrophysical subjects, using that description to include almost all astronomical matters outside the domain of celestial mechanics and the measures of the positions of the heavenly bodies.

The editorial board is an exceedingly strong one. Professors Hale and Keeler are assisted, as in the direction of *Astronomy and Astrophysics*, by Professors Ames, Campbell, Crew, Frost, and Wadsworth. But in addition to these, France, Sweden, England, Italy and Germany are severally represented by the associate editors, MM. Cornu and Dunér, Dr. Huggins, and Professors Tacchini and Vogel. Whilst in America, Professors Hastings, Michelson, E. C. Pickering, Rowland and Young have also consented to act in a similar capacity.

The importance and high technical value of many of the articles which have appeared in the *Astrophysical Journal* during its first year of publication are a sufficient justification of its origination. A yet further value is given to it by the results of the first annual meeting of its editorial board At this meeting, held 1894 November 2, a circular was drawn up and sent to all the absent members of the board, asking their opinion on a number of questions. At the second annual meeting, held on 1895 October 17, votes having been received from all the members, the following standards were adopted.

1. The Rowland scale of wave-lengths as represented by the wave-length tables now being published in the *Astrophysical Journal.*

2. The "tenth metre," or ten-millionth of a millimetre, as the unit in which wave-lengths should be expressed.

3. The kilometre, as the unit to be used in measurements of motion in the line of sight.

4. The nomenclature proposed by Huggins and Vogel for the hydrogen series, in which the lines are designated Hα, Hβ, Hγ, &c., beginning at the red end, and continuing through the entire series.

5. Maps of spectra to be printed with the red end on the right.

6. Tables of wave-lengths to be printed with the shorter wave-lengths at the top.

All the editors favoured the use of these standards, not only in the *Astrophysical Journal*, but also in all other publications of a similar character; and it is to be hoped and expected that the decisions of so powerful a board, and one so international in its character, will be followed by all interested in astrophysical fields of work.

A useful feature of the *Journal* is the bibliography of recent astrophysical literature which is supplied in it month by month.

The Variation of Latitude, and the Constant of Nutation.

Under date 1895 June Dr. Foerster, of Berlin, published a memorandum suggesting that observations for following the variations of latitude should be undertaken at four observatories in the same latitude, viz. :—

Licata in Sicily,	long.	14°	E.
Shirakawa in Japan	,,	140°	,,
Felton in California	,,	238°	,,
Petersburg in Virginia	,,	283°	,,

He further suggested that this work should be undertaken by the Geodetic Association, and accordingly his proposals were considered at the October Conference. A new international Geodetic Convention was drawn up, involving increased annual contributions from the nations joining it, in order that this work on the variation of latitude might be undertaken. The head-quarters of the Central Bureau are in Berlin; the Conference is to meet at least once in three years; and the expenses are estimated at 3,000*l.* a year for the next ten years; towards which the contribution of England (determined by its population), if it joined the Convention, would be 300*l.* a year. The reasons for this new departure are embodied in a "Notice justificative"; and the following extracts from this notice (kindly sent to the Council by Professor Foerster, in reply to a request by the Secretary) will explain the importance of this new departure :—

"NOTICE JUSTIFICATIVE SUR L'AUGMENTATION DU BUDGET ANNUEL DE L'ASSOCIATION GÉODÉSIQUE INTERNATIONALE.

"Les nombreuses observations de latitude que, dans le courant des six dernières années, l'Association géodésique a soit provoquées et appuyées, soit organisées directement, ainsi que les travaux analogues exécutés dans plusieurs observatoires, ont fourni la preuve évidente de variations sensibles dans la position de l'axe terrestre.

"Les variations constatées jusqu'à présent sont, il est vrai, assez faibles; toutefois elles dépassent sensiblement l'incertitude

avec laquelle la géodésie actuelle détermine les coordonnées géographiques.

"S'il était démontré que ces variations sont rigoureusement périodiques, de sorte que le pôle décrirait une courbe fermée, on pourrait, au moyen d'une série d'observations étendues sur quelques années, en déterminer la période et l'amplitude, et corriger les positions géographiques en raison de ces mouvements de l'axe terrestre.

"Mais, ni les observations, ni une des théories imaginées pour en rendre compte et pour expliquer ces phénomènes, ne donnent jusqu'à présent cette certitude. Au contraire, le travail d'ensemble que le Bureau central a fait exécuter par M. le professeur Albrecht sur les variations de latitude connues, et qui a été communiqué à la XI^me Conférence géodésique, conduit à envisager ces changements de l'axe terrestre comme un phénomène très compliqué, qu'on ne parvient pas à expliquer par une théorie simple, ni à représenter exactement par des formules de calcul, et dont les nombreuses séries d'observations des six ans ne suffisent pas à démontrer le caractère strictement périodique.

"Si à côté des variations à courtes périodes on devait reconnaître un mouvement de l'axe terrestre, progressif dans un certain sens, quelque faible qu'il fût, il résulterait, comme Helmholtz et Schiaparelli l'ont fait voir, d'un tel déplacement continuel de l'axe, des changements considérables dans la distribution des masses, non seulement du niveau des mers, mais aussi dans la configuration et l'arrangement des couches soi-disant fixes de l'écorce, mais qui sont probablement encore plastiques dans une certaine mesure, de sorte que ces modifications et le développement ultérieur des variations de l'axe devraient nécessairement être pris en considération dans les travaux pratiques de géodésie.

"En premier lieu, ce seraient les nivellements et les travaux hydrologiques, surtout les recherches importantes sur les phénomènes de marée à longue période, qui s'en ressentiraient.

"On peut donc affirmer que la continuation et le perfectionnement des mesures de variations de latitude, commencées sur une échelle plus grande à l'aide de l'organisation géodésique internationale, intéressent autant la géodésie que l'astronomie ou la physique du globe. Si l'on parvenait à montrer—ce qui ne serait en tout cas possible qu'en continuant les observations soigneusement et sur une vaste échelle—que les mouvements de l'axe terrestre ne s'éloignent pas, pendant un laps de temps de dix ans, sensiblement d'une forme purement périodique, dans ce cas seulement on serait justifié de prétendre que, dans l'intérêt purement géodésique, on pourrait interrompre ces recherches pendant un certain temps, tandis que les intérêts de l'astronomie et de la physique du globe exigeraient même alors la continuation régulière et générale de ces études.

"Pour pouvoir éclairer les incertitudes qui règnent encore sur

la nature et la forme future des changements de l'axe terrestre dont la première phase des recherches a démontré l'existence, il sera désormais indispensable d'organiser le plus tôt possible un système d'observations par lesquelles on pourra espérer d'arriver à la plus grande précision des mesures, en éliminant complètement l'influence considérable des mouvements propres des étoiles, que nous ne connaissons pas encore suffisamment pour en tenir compte dans ces recherches.

"Or, on ne peut réaliser cette condition d'une manière à la fois précise et simple qu'en organisant des observations simultanées de latitude au moyen de la méthode la plus exacte, dans plusieurs stations, réparties sur le même parallèle aussi également que possible, et dans lesquelles on emploierait les mêmes couples d'étoiles ; pour atteindre la plus parfaite simultanéité de ces observations, il importe de choisir le parallèle de façon que les conditions climatériques des différentes stations, surtout au point de vue de la clarté du ciel, soient les plus favorables. . . .

"Un argument important, qui vient encore s'ajouter à tous ceux dont il a été question jusqu'ici, est fourni par les perturbations systématiques de réfraction qui sont à craindre dans les salles d'observation, et sur lesquelles M. van de Sande Bakhuyzen et dernièrement l'Institut géodésique de Potsdam ont attiré l'attention des astronomes. Sous l'influence de certaines constructions des murs et des toits, comme on les rencontre dans la plupart des observatoires actuels, il peut se former des stratifications d'air de températures différentes qui, dans certains cas, sont assez durables et ont des gradients assez forts pour provoquer des perturbations dans la réfraction et rendre illusoires les conditions présumées pour l'emploi des meilleures méthodes qui servent à déterminer la hauteur du pôle.

"Les causes de ces perturbations sont bien plus difficiles à écarter avec les constructions compliquées de la plupart des grands observatoires, que lorsqu'on a affaire à de simples petites cabanes d'observation, qu'on peut placer en évitant autant que possible toute asymétrie affectant les températures dans les environs immédiats, et qui se réduisent à un simple abri pour l'unique instrument dont on a besoin dans ces observations ; de cette manière, les rayons des étoiles qui tombent sur l'objectif de la lunette parcourent un très petit chemin à travers le local d'observation et on peut s'affranchir de toute influence des températures des murs et des toits sur la marche des rayons.

"Ce seul argument suffirait pour réfuter l'opinion qu'il faudrait se contenter, pour les recherches en question, des moyens et des installations des observatoires existants. . . .

"Et encore ne faut-il pas oublier que—comme il a été prouvé plus haut—cette manière isolée et individuelle de procéder ne permettrait pas de décider sûrement, dans une dizaine d'années, l'importante question, si et dans quelle étendue il existe des

variations continuant dans le même sens pendant un certain temps.

"FOERSTER,

"Président de la XI^{me} Conférence générale de l'Association géodésique internationale et Membre de la Commission spéciale nommée par la Commission permanente pour l'étude des variations de la position de l'axe terrestre.

Berlin: Décembre 1895."

The discussion by Professor Albrecht of the observations on variation of latitude 1890–95 appears in the *Astronomische Nachrichten*, No. 3,333, published on 1896 February 8, and will thus more properly be alluded to in next year's Report. It deals with observations made at Kasan, Pulkowa, Prague, Berlin, Bamberg, Kiel, Karlsruhe, Strasburg, New York, Bethlehem, Vienna, Potsdam, &c. &c.; and a diagram is given showing the motion of the north pole as a curve contained within a square of side $0''\cdot60$, but not a closed curve.

Dr. Chandler's work generally is referred to in the President's Address. During the year he has published one or two interesting notes on latitude variation, and an ephemeris for the years 1893–96 for the correction of meridian and other observations for these inequalities. Quite recently he has redetermined the constant of nutation from Greenwich mural circle observations during the years 1825–1848, after correction for variation of latitude, and finds the result $9''\cdot192$. Collecting previous results and weighting them, he obtains the definitive result $9''\cdot202$ for this constant, the corresponding reciprocal of the Moon's mass being 81·80 if $50''\cdot36$ is used for the lunar-solar precession. The Greenwich observations discussed relate to 36 fundamental stars distributed over the sky, and in a subsequent paper he discusses the declinations of these stars and compares them with Boss's system. The agreement is so satisfactory, and the discordance of the system of Auwers's *Fundamental-Catalog* so marked, that Dr. Chandler considers the time has now come when the latter must be given up as a standard, and recourse had to a system based on the observations of this century.

The Adams Memorial.

In the month of May in the past year the memorial medallion of the late Professor Adams was unveiled in Westminster Abbey. The simple words of the inscription—

JOHN COUCH ADAMS.

PLANETAM NEPTUNUM CALCULO MONSTRAVIT, MDCCCXLV.

record an achievement which made Englishmen wish to commemorate Adams by a memorial near to that of Newton.

There are many who look forward to the completion of another part of the memorial, namely, the publication in collected form of the papers of which many remained in MS. at the time of Professor Adams's death in 1892. It is therefore of interest to record that the first volume containing the already published papers is printed off and only awaits the introductory scientific memoir for publication; the second volume, which is to consist of researches and other matter communicated in lectures in the University of Cambridge, is being prepared by Professor R. A. Sampson, of Durham. We understand that Professor Sampson is well forward with the work, having completed the collation of several sets of MS. notes relating to the lectures on Lunar Theory and on *Jupiter's* satellites. The unpublished magnetic researches have been prepared for publication by Professor W. G. Adams, and are practically ready for publication.

The Universal or Zone-Time System.

During the year 1895 the Australian colonies have each adopted for general use a time-system which is based directly on the meridian of Greenwich. The Australian Continent, under this system, is not divided into zones bounded accurately by meridians 15° apart, as is the Continent of America, but the time-zones follow exactly the territorial divisions of the Continent. Thus the time in use in Western Australia is 8 hours, in South Australia 9 hours, in Victoria, New South Wales, Queensland, Tasmania, 10 hours fast on Greenwich time. This change was made in Queensland on 1895 June 1, and in the other colonies on 1895 February 1. Acts have been passed in the Parliaments of New South Wales, Victoria, South Australia, and Queensland, making the times as above described the legal time for these territories, but we have no information of similar Acts applying to the other colonies.

An Act (Definition of Time Act, 1895) has been passed in the Legislative Assembly of the Province of Ontario, making legal the standard time which has been in use in Ontario, as part of the zone-time system adopted over the whole of North America, for several years past. This is believed to be the first legislation on the subject in North America, and will probably be followed by similar enactments for other territories. The wording of the Act runs—"As regards that part of the province which lies east of the meridian of 87° west longitude, standard time shall be reckoned as 5 hours behind Greenwich time, and as regards that part of the province which lies west of the said meridian, standard time shall be reckoned as 6 hours behind Greenwich time."

A section of the Act reads—"The hours of the day may in any locality be numbered in one series up to 24, according to the '24-hour notation' so called, and the numbers so used shall be equally valid with the numbers used in the division of the day into two series of 12 hours distinguished as A.M. and P.M."

There is no information to hand that the Bill which is before the Austrian Parliament for the adoption of Central European time in Austria is yet passed.

H. P. H.

New Observatories.

No new observatories have actually been made since the date of the last Report, but the foundation of one such institution has been determined on, and it has been lately announced that two others are in process of erection. The first of these, and the one which promises to be the most important, as being the State observatory of a colony likely to grow in resources, is to be at Perth, Western Australia. The Government of this colony has voted a sufficient sum of money to provide a good Astronomical Observatory, containing a transit-circle and a photographic equatorial, and a residence for the astronomer in charge.

Sir John Forrest, the Premier of the Colony, consulted Sir Charles Todd, who prepared detailed specifications for the two instruments above-mentioned. The transit-circle is to have an object-glass of 6 inches in diameter, and circles (there are to be two, as the instrument is to be reversible) of 30 inches diameter. The astrographic equatorial is to have a 13-inch photo-telescope and a 10-inch visual telescope driven by electrically controlled clockwork. These instruments are now being made, the transit-circle by Messrs. Troughton & Simms, the equatorial and dome by Sir Howard Grubb, under the superintendence of the Astronomer Royal, who has consented to help the Colonial Government with his advice in this matter.

Mr. W. Ernest Cooke, M.A., who has been assistant to Sir Charles Todd at the Adelaide Observatory since 1882, has been appointed to the directorship of this Observatory.

The other two projected institutions are for educational purposes. One, called the Flower Observatory, is being erected by the University of Pennsylvania, on a site five miles west of the present University buildings and two miles beyond the city limits. This Observatory is to furnish facilities for instruction in astronomy and for research. Professor C. L. Doolittle is to have charge of this Observatory, and will have in his care an 18-inch equatorial with spectroscope, a meridian circle and a zenith telescope, each of 4 inches aperture.

The University of Minnesota, Maine, U.S.A., is also having an observatory set up for similar purposes. The principal instrument at present is said to be an equatorial of 10 inches aperture, with an additional lens for photography, and provided with a spectroscope and a photograph micrometer as accessories. Professor Leavenworth, of Haverford College Observatory, is to have charge of this observatory.

H. P. H.

Papers read before the Society from March 1895 to January 1896.

1895.

Mar. 8. Ephemeris of the five inner satellites of *Saturn*, 1895 A. Marth.

Filar micrometer measures of the diameters of the four bright satellites of *Jupiter*, made with the 36-inch equatorial of the Lick Observatory. E. E. Barnard.

The transit of *Mercury*, 1894 November 10. W. F. Gale.

A list of probably new double stars. R. T. A. Innes.

The transit of *Mercury*, 1894 November 10, observed in Queensland. J. P. Thomson.

Micrometrical measures of the ball and ring system of the planet *Saturn*, and measures of his satellite *Titan*, made with the 36 inch equatorial of the Lick Observatory. E. E. Barnard.

Double star measures, 1892–94. W. H. Maw.

Results of double star measures with the 8-inch equatorial at Windsor, New South Wales, in 1894. J. Tebbutt.

Notes on the variable stars X and W *Sagittarii*. Lieutenant-Colonel E. E. Markwick.

Note on a suggested form of equatorial mounting for a (modified) Newtonian reflector. Rev. C. D. P. Davies.

On the proper motion of the star *Cephei* 24 (Hev.). W. T. Lynn.

On the proper motion of the star *B.A.C.* 793. W. T. Lynn.

The Wilsonian theory and the Stonyhurst drawings of Sun-spots. Rev. W. Sidgreaves.

Observations of Encke's Comet made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

An apparatus for mechanically calculating star corrections. W. E. Cooke.

Note on the above paper. H. H. Turner.

A negative optical proof of the absence of seas in *Mars*. H. Dennis Taylor.

A systematic comparison between the places of stars given in the Cape Catalogue for 1880 and the Radcliffe Catalogue for 1890. E. J. Stone.

Mar. 8. On the mean places of eight southern close polar stars. E. J. Stone.

Observations of the vertical diameter of the planet *Jupiter*. T. J. Moore.

Apr. 10. Equatorial comparisons of *Jupiter* and 1 *Geminorum*. John Tebbutt.

On a modified form of Cassegrain telescope. W. R. Brooks.

Note on the total eclipse of the Moon, 1895 March 10. H. F. Newall.

Note on η *Cassiopeiæ*. T. Lewis.

Occultation of *Antares*, 1894 October 31. R. T. A. Innes.

The Brachy telescope of Messrs. Fritsch and Forster of Vienna. A. A. Common.

Observations of occultations of stars during the lunar eclipse of 1895 March 10, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

The total eclipse of the Moon, 1895 March 10. G. J. Newbegin.

The solar eclipse of 1895 March 25. G. J. Newbegin.

Pallas and *Vesta* in 1895. W. W. Bryant.

Observation of the partial eclipse of 1895 March 25, at the Armagh Observatory. J. L. E. Dreyer.

Observations of Occultations of stars during the total eclipse of the Moon on 1895 March 10, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Notes on the observations for coincidence of the collimators in flexure determinations with the Greenwich transit-circle, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

May 10. Occultations observed at Harrow during the total eclipse of the Moon, 1895 March 10. Lieutenant-Colonel G. L. Tupman.

Partial eclipse of the Sun, 1895 March 25. A. A. Rambaut.

On the variable nebula of Hind and Struve in *Taurus*, and on the nebulous condition of the star *T Tauri*. E. E. Barnard.

On the rotation of *Saturn* in 1894. A. Stanley Williams.

Observations of minor planets made at the Observatory, Tacubaya, Mexico. F. Valle.

The thermal radiation from Sun-spots: Observations made at Daramona, Streete, Co. Westmeath. W. E. Wilson.

On a fixed system of star co-ordinates (abstract). R. H. M. Bosanquet.

Photograph of the nebula near 15 *Monocerotis*. Isaac Roberts.

May 10. Photograph of the Crab Nebula M 1 *Tauri*. Isaac Roberts.

Observations of the phenomena of *Jupiter's* satellites, and of the transits of the red spot, dark and bright spots, &c., made at Bermerside Observatory, Halifax, during the winter of 1894–95. J. Gledhill.

Answer to an inquiry in the *Bulletin Astronomique* for 1895 May. E. J. Stone.

Micrometer measurements of *Phobos*, the inner satellite of *Mars*, during the opposition of 1894. H. F. Newall.

June 14. On a photographic study of the Earth-lit portion of the new Moon. E. E. Barnard.

On a great photographic nebula in *Scorpio* near *Antares*. E. E. Barnard.

Note on the proper motion of *Arcturus*. W. T. Lynn.

Observations of *Jupiter*. W. F. Denning.

The relation between precession and proper motion. R. H. M. Bosanquet.

A general method for facilitating the solution of Kepler's equation by mechanical means. T. J. J. See.

On the accuracy of late catalogues of declinations of standard stars. T. H. Safford.

Ephemeris for physical observations of *Jupiter*, 1895–96. A. Marth.

On a catalogue of stars in the Calendarium of Mohammad Al Achsasi Al Mouakket. E. B. Knobel.

Diameters of *Jupiter* and satellites observed at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

A determination of the mean N.P.D., 1790 January 0, of γ *Draconis* from observations made at Oxford by Dr. Hornsby. E. J. Stone.

Meridian observations of *Sirius* and *Procyon* at the Royal Observatory, Greenwich, 1836–94. W. G. Thackeray.

Note on the binary star ι *Leonis*. Alice Everett.

Further measures of double stars made at the Temple Observatory, Rugby, by G. M. Seabroke and H. P. Highton.

On the angular distance of two stars in the *Pleiades* suitable for determining the value of a micrometer screw. H. H. Turner.

Nov. 8. Results of micrometer comparisons of *Saturn* and κ *Virginis*. John Tebbutt.

Observations of phenomena of *Jupiter's* satellites with the 8-inch equatorial at Windsor, New South Wales, in the year 1895. John Tebbutt.

Nov. 8. Comparisons of the Sun's longitudes for 1900, computed from Newcomb's tables of the Sun, with those computed from Le Verrier's tables. A. M. W. Downing.

Description of a mechanical apparatus for computing refractions. W. E. Cooke.

Micrometrical determinations of the diameters of the minor planets, *Ceres* (1), *Pallas* (2), *Juno* (3), and *Vesta* (4), made with the 36-inch equatorial of the Lick Observatory, and on the albedos of these planets. E. E. Barnard.

Ephemeris for physical observations of *Jupiter*, 1895–96 (concluded). A. Marth.

On the extended nebulosity about 15 *Monocerotis*. E. E. Barnard.

Data for computing the positions of the satellites of *Jupiter*, 1895–96. A. Marth.

Invisibility of Hind's variable nebula (N.G.C. 1555). E. E. Barnard.

Observations of Encke's Comet, 1894–95, made at the National Observatory, Tacubaya, Mexico. F. Valle.

Observations of minor planets made at the National Observatory, Tacubaya, Mexico. F. Valle.

Note on Hansen's lunar and planetary theories. E. W. Brown.

Results of filar micrometer comparisons of *Saturn* and 96 *Virginis*, and of *Ceres* with neighbouring stars. John Tebbutt.

Photograph of the nebula ♅ VI. 41, and a new nebula in *Draco*. Isaac Roberts.

Photograph of the cluster ♅ VIII. 76, and of a new nebula in *Cygnus*. Isaac Roberts.

Observations of the variable star *T Centauri*. Lieut.-Colonel E. E. Markwick.

Mean areas and heliographic latitudes of sun-spots, deduced from photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Diameters of *Saturn* and his rings observed during the opposition of 1895 at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on the discovery of the graphical method for solving Kepler's equation by means of a curve of sines. T. J. J. See.

Note on the value of the longitude in the lunar theory when the Sun's mass is put zero. P. H. Cowell.

The orbit of Σ 1879. T. Lewis.

Note on the measurement of paper prints of stellar photographs. H. H. Turner.

Dec. 13. The radiant point of the October meteors. W. F. Denning.

Dec. 13. Setting apparatus for a transit-circle. W. E. Cooke.
On the proper motion of Lacaille 4336. R. T. A. Innes.
On the proper motion of μ *Cassiopeiæ*. W. T. Lynn.
Photograph of the spiral nebula M. 33 *Trianguli*. Isaac Roberts.
Note on some remarks of M. O. Callandreau in the *Bulletin Astronomique* for 1895 November. E. J. Stone.
Note on a crayon drawing of the Moon by John Russell, R.A., at the Radcliffe Observatory, Oxford. E. J. Stone.
Observations of comets *Encke* 1894 and *Swift* 1895 August 20 made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.
Observations of Perrine's Comet (*c* 1895) made with the altazimuth at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
Observation of variable stars. The late George Knott.
Note on Newcomb's Tables of the Sun. A. M. W. Downing.

1896 Jan. 10. Details of the total solar eclipse of 1896 August 8–9 for Kushiro, in the island of Yezo. Communicated by the Superintendent of the *Nautical Almanac*.
Photograph of the *Owl* nebula M 97, and of the nebula ℍ V. 46 *Ursæ Majoris*. Isaac Roberts.
Photograph of the cluster ℍ VII. 66, and of the nebula ℍ IV. 75 *Cephei*. Isaac Roberts.
Micrometrical measures of the ball and ring system of *Saturn*, and measures of the diameter of his satellite *Titan*, with some remarks on large and small telescopes. E. E. Barnard.
Observations of Comet *d* 1895 (Brooks) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
Observations of occultations of stars by the Moon, and of the phenomena of *Jupiter's* satellites, made in the year 1895 at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
Ephemeris for physical observations of the Moon 1896. A. Marth.
On the drift of the surface material of *Jupiter* in different latitudes. A. Stanley Williams.
On the determination of positions of stars for the Astrographic catalogue at the Royal Observatory, Greenwich. W. H. M. Christie and F. W. Dyson.
Expressions for the elliptic co-ordinates of a moving point to the seventh order of small quantities. E. J. Stone.

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ADDRESS

Delivered by the President, A. A. Common, LL.D., F.R.S., on presenting the Gold Medal to Mr. S. C. Chandler.

The Council have awarded the Gold Medal to our Associate, Mr. Seth C. Chandler, "for his discussion of the variation of latitude, his work on variable stars, and other astronomical investigations"; and I have now to state to the Society the considerations that prompted this award, which happily I can do by a very brief review of the work of our medallist.

Before doing this I must express my regret that this chair is not occupied by one more familiar with the class of work under review, by one who could have subjected it to that critical comment to which the President's address on this occasion is so often devoted, and which I am sure the work in question would so well bear. Such criticism of our medallist's work is perhaps less needed on this occasion, as it has already been subjected to the competent examination of three of our Associates who are also medallists (Newcomb, Gould, and Asaph Hall), who signed the report of the Watson Trustees to the American Academy of Science, when the Academy in 1894 awarded the Watson Medal to Mr. Chandler. The fact that my own work is on other lines does not preclude me from expressing the great pleasure it has been to read again more carefully, for the purpose of this address, the many papers containing Mr. Chandler's contributions to astronomy, and my admiration of his work, particularly of that laborious portion resulting in the discovery of the law of variation of latitude.

This question of the variation of latitude in its present aspect dates back only a very few years. It was first noticed in our Annual Report in 1891, but there is no note in the 1892 Report. By the date of our annual meeting in 1893, however, the chief discovery of our medallist (the variation in a period of 428 days) had been made, and eight or nine papers had already appeared of that brilliant series of researches by which the complete law of variation has been practically established. This series, including investigations arising from the main inquiry, has been continued to the present time; and the consequences of Mr. Chandler's discoveries are so far-reaching, and his energy in following them up is so unfailing, that we may hope for equally interesting

results in the future. But the work has already reached a stage of completeness in that the main investigation is concluded. Our medallist has sufficiently elucidated the law of latitude variation to publish an ephemeris of it. In his own words, "The relative motion of the earth's axis of figure and rotation is governed by a law, synthetically derived from observation, whose constants are so accurately known that we can with certainty compute in advance tables of the variations of latitude for any given station," and he proceeds to give such tables for the years 1893–96 for which "a convenient and suitable place in the future would be the various astronomical ephemerides." Remembering that the variation of latitude was not much more than suspected some five years ago, and that there was not even a suspicion of the true *law* of variation (except, perhaps, in the fertile brain of our medallist), the proposition to now print such tables of prediction side by side with tables of the planets is somewhat startling. But a careful examination of Mr. Chandler's work forces upon us the conviction that his confidence in it is justifiable. In the past four or five years he has found time to discuss, exhaustively for the present purpose, all the observations available from Bradley to the present time, so that as regards their foundation his ephemerides are well worthy of a place beside others; while the close accordance of results derived from such a large number of independent sources is a guarantee of the accuracy of the law finally adopted.

The history of these investigations is most interesting. More than a century ago it was shown by Euler that if the axis round which the Earth revolves be not coincident with the axis of figure, the position of the former in the earth would shortly change, revolving round the axis of figure in 305 days. Euler's work started with the assumption that the Earth was a perfectly rigid body, which is not the case, and we shall presently see how this assumption affects the result; but it never occurred to anyone until a year or two ago to consider the effect of non-rigidity. Euler's result was accepted, and search was made for indications of this motion of the axis of rotation in a period of 305 days, or ten months; but no such motion was found, though several investigators tried to detect it. The first to make the attempt, though unsuccessfully, was C. A. F. Peters, then at Pulkowa. Negative results were also obtained at Washington, at Pulkowa again by Nyrén, and by Clerk-Maxwell and Downing from Greenwich observations. It was thus supposed that the axes of rotation and figure were sensibly coincident, and little further interest was taken in the matter. The first fifty volumes of our *Monthly Notices* contain no reference to the variation of latitude beyond the paper by Downing, of two or three pages, in which he shows that ten years' Greenwich observations of *Polaris* show no 305 day variation.

The question was definitely reopened by Küstner, of Berlin. In 1885 he remarked that some curious discordances affecting

Nyrén's observations with the prime-vertical transit could be accounted for by supposing a change of latitude; and in 1888 he published a memoir on the constant of aberration, as deduced from a series of observations made by him at Berlin in 1884–5, from which it appeared incidentally that the latitude of the observatory must have changed during the period of observation. So conclusive was this demonstration of change that special attention was forthwith directed to the point by the International Geodetic Association. Under its auspices special observations were organised to detect any changes in latitude at three or four observatories, with immediate and conspicuous success. I cannot here follow the course of this observational work, which has proceeded continuously up to the present time, and which it is now proposed to extend and develop further. The investigations of our medallist have been conducted to a large extent independently of it (though latterly he has made excellent use of the valuable material resulting from these observations), and we are to-day concerned especially with his work alone.

As above stated, it was Dr. Küstner who first called the attention of the astronomical world to the variation of latitude; but similar ideas had occurred to Mr. Chandler at about the same time, though circumstances prevented him following them up. In the years 1884–5 he made a thirteen months' series of observations with the almucantar (an instrument of his own devising, of which I shall presently speak), which revealed a progressive change in the value for the latitude given by this instrument, and he was unable to refer this apparent change to anything instrumental. As he says later, he hesitated then to ascribe it to a real change of latitude without further investigation, which he was not able to undertake at the time. Six years later, when the change had been meanwhile strikingly confirmed by the publication of Küstner's observations (also in 1884–5), and general attention had been called to the matter, Mr. Chandler was able to resume the inquiry, and his success in finding the key to the solution of the problem was almost immediate. His work is detailed in some score of papers in the *Astronomical Journal*, following one another with marvellous rapidity, considering that the amount of work represented by each was in general undertaken and completed in the interval since the last. For when sure that he had got hold of the real thread, Mr. Chandler began to publish at once without waiting to unravel the tangle completely. As he cleared each successive length, he presented it to the world; and this method gives a freshness to the resulting series of papers which can only be realised by reading them in the original.

The first important step, the detection of the fourteen months period in the latitude, resulted from an examination of the Pulkowa vertical-circle observations, 1863–1875, and the Washington vertical-circle observations 1862–1867. This periodicity was confirmed by examination of observations at Melbourne and

Leyden at about the same time. Here was a singular discrepancy with Euler's theory; which had so definitely indicated a period of ten months, if any, that none other had hitherto been looked for. An explanation of the apparent conflict between theory and observation was, however, soon given by Professor Newcomb, who pointed out that a deviation from absolute rigidity in the Earth would alter the Eulerian period. More elaborate investigations of this point have since been made by Woodward in America and Hough * in England, and there seems little doubt that this explanation, fortunately so quickly forthcoming, is the true one. But the few months during which theory and observation were not reconciled had a marked effect upon the future course of Mr. Chandler's work, which was from that time characterised by a stern resolution to set aside any teaching of adopted theories and to let the observations speak for themselves. I do not mean to suggest that this resolution was born after the beginning of his researches, for it can be traced in his first papers; but it was undoubtedly much strengthened by the events of these few months, during which his results were regarded by many as very questionable, owing to their want of accordance with a theory afterwards shown to be defective. And his resolve stood him in good stead, for his deductions from observation were soon again at variance with theory. On examining earlier observations in Bradley's time he found that the fourteen months' period had disappeared, and in its place was a variation in twelve months of larger amplitude: and there were indications of a progressive change from one period to the other. These results, promptly and fearlessly announced, brought a new wave of scepticism, and almost carried back those who had been won over (like Professor Newcomb) into the opposition camp. Fixed in his determination, however, to be undismayed by any apparent conflict with theory, our medallist went on patiently examining huge masses of observations wherever he could find them suitable for his purpose. The situation is so dramatic and the study of it such an incentive to true scientific investigation that I make no apology for re-

* In a paper communicated to the Royal Society last month, Mr. Hough gives an analytical investigation of the motion of simple rotation about a principal axis, taking into account elastic distortions due to variations in centrifugal force; the results are found to agree in the main with those obtained by Professor Newcomb from geometrical considerations. The analysis deals with the case of a homogeneous spheroid of revolution, the ellipticity being such that the body is free from strain when rotating uniformly. Such a spheroid, if of the same size and mean density of the earth and rotating with the same angular velocity, would oscillate in a period of 232 days if perfectly rigid; it is shown that this period would be extended to 335 days in virtue of elastic distortions if the rigidity were equivalent to that of steel. In the case of the Earth the period would be still further prolonged in consequence of variations in density, and the period which corresponds to the above degree of rigidity is estimated at about 440 days; whence it is concluded that the observed period may be accounted for by supposing that the Earth is capable of elastic deformation, and that its effective rigidity is slightly in excess of that of steel.

calling Mr. Chandler's own statement of it, which has already been quoted in the Report for 1893;—

"It should first be said that in the beginning these investigations I deliberately put aside all teachings of theory, because it seemed to me high time that the facts should be examined by a purely inductive process; that the nugatory results of all attempts to detect the existence of the Eulerian period probably arose from a defect of the theory itself; and that the entangled condition of the whole subject required that it should be examined afresh by processes unfettered by any preconceived notions whatever. . . . The appeal to observation, treated irrespective of theory, in the present series of papers, shows that a rotation of the pole really exists, but (*a*) at a daily rate of but $0^\circ\!\cdot\!85$ (for 1875), and (*b*) that this velocity is subject to a slow retardation, which, in its turn, is not uniform. . . . The result (*a*) was at first pronounced impossible, and is even now so regarded in some quarters. Professor Newcomb, however, soon after found the defect in the theory, and is now as cordially in favour of the result given by observation as he was originally against it. . . . Now, may it not reasonably be asked if the direct deduction from observation has led to the correction of theory in the first particular, is it beyond hope that it may do so in regard to the second?"

Six weeks after the publication of these words "theory and observation were again brought into complete accord," but this time by Mr. Chandler himself. By re-arranging his material he found that the variation of slowly changing period and amplitude which had scared away his theoretical friends was really a superposition of two variations, one in fourteen months and the other in twelve, one of which gradually overtakes the other in the familiar manner. He has gradually built up the complete description of this compound motion, and has shown that the former component is due to a circular revolution of the pole of the axis of figure about the pole of rotation in a radius of 14 feet: and the latter to the motion of the pole of figure in an ellipse 25 feet long and 8 feet broad, the major axis being inclined at present about 45° to the Greenwich meridian. There are indications of slow changes in these elements, and other details on which I need not here dwell. Rather would I call your attention to one or two general characteristics of Mr. Chandler's work, which stamp it as in every way worthy of the honour now conferred upon him.

I have already mentioned his determined independence of preconceived hypotheses, and his resolution to appeal to the facts themselves, and to them alone. An equally striking feature of his work is the enormous mass of it, of which it is difficult to give an adequate idea. The fact that in the last five years he has contributed fifty papers to the *Astronomical Journal*, covering in all 150 pages, is in itself noteworthy; but many of these papers represent in a few pages an amount of work which it is

almost impossible to estimate. Paper No. VI. of the series on variation of latitude, for instance, gives the results of the examination of forty-five different series of observations at different observatories. Three other papers of the above fifty are the Second Catalogue of Variable Stars and its two supplements; and a short note, of only half a page, announcing the recent discovery of a variable period of 5½ hours, represents a large amount of work at the telescope. Throughout the absorbing researches on latitude Mr. Chandler never lost touch with variable stars and comets, on which he had laboured for many years; and I might emphasise not only the amount but the variety of his work. Yet I trust I may not appear fanciful in suggesting that in this variety of work there is a unifying principle, for it seems to me that Mr. Chandler's genius for the detection of a new period is manifest throughout. His work on variable stars led up to his great discovery in the variation of latitude. The two Catalogues of Variable Stars with their supplements, which he has published, are no mere compilations, but represent the critical scrutiny of all available observations; the correction of many elements and the revision of others; the detection of waves subsidiary to the main light-curve; and, finally, several actual discoveries by the author himself. Such work as this trained his natural delicacy of perception of periodicity, and he became an expert, thoroughly competent to deal with such problems. To detect an existing periodicity or to trace the true cause of abnormal observations may seem an easy matter to those who have not tried it, but history proves the contrary. Thirty-nine years ago our Medal was awarded to M. Schwabe for his discovery of the periodicity of solar spots. The occupant of this chair then cited several authorities to show that for a century previous to the commencement of Schwabe's work no suspicion of periodicity had been awakened—nay, more, that any systematic regularity in the appearance of sun-spots was categorically denied. Schwabe's discovery was only made as the result of thirty years' unremitting labour at the telescope, though it is difficult for us now to imagine how it could have been overlooked by the most casual observer, so different is the situation before and after the discovery. A minor instance of the difficulties attending the detection of a true period has recently been afforded by our medallist himself in the case of his new variable of 5½ hours period.

"It may not be amiss to add," he says, "that I discovered the variability of this star more than a year ago, but erroneously inferred that it was of the Algol type, with a period of 2·06 or 2·07 days; a mistake due to the near commensurability of nine of the true periods with two solar days." Thus the star had run through its changes some 1,500 times while under careful scrutiny before its true period was detected. Most of the time it was, of course, not available for observation owing to daylight and cloud: and this necessary intermittence in the observations with the

masking of the period by commensurability with others, as above-mentioned, are two of the chief difficulties in such work. We have recently seen a remarkable illustration of these difficulties in the controversy respecting the rotation periods of *Mercury* and *Venus*. These planets can only be observed intermittently at intervals of about a day, and it is not yet established beyond question whether their rotation periods are commensurable with the mean solar day or with their periods of revolution round the Sun. It is difficult to imagine what would have been the case with that greatest of modern discoveries—the finding of *Neptune*—if a working hypothesis in the shape of the assumed elements indicated by Bode's law had not existed, or how long another important discovery, that of argon, and indirectly of helium, would have been postponed, if the anomalous observations of the weight of nitrogen had not been traced to their true cause by Lord Rayleigh.

So far I have spoken chiefly of Mr. Chandler's great discovery of the true law of variation of latitude; and this address has already run to such a length that his other work, sound and original as it is, must be reviewed very briefly. His Catalogues of Variable Stars, and his observations and discoveries in this department of science, have already been mentioned, and though much might be said in their praise, I must reluctantly forego this privilege on the present occasion. I would, however, claim your attention for a few moments to the instrument devised by Mr. Chandler, and called by him the almucantar, embodying as it does a new principle applied with great success to an observing instrument of precision.

A full account of this instrument, with the methods of using it and the observations made, extending over a period of thirteen months, forms Vol. XVII. of the *Annals of Harvard College Observatory*. It is the outcome of an idea which occurred to Mr. Chandler that another method of making that class of observation for which meridian instruments are used might be accomplished by substituting for the meridian as a fundamental plane of reference the small circle perpendicular to the meridian passing through the pole, and for the motion of rotation determined by the pivots of a horizontal axis, one determined by gravitational action round an imaginary vertical axis. Two ways suggested themselves of carrying out this object: to suspend the instrument like a pendulum, or to float it on mercury. Both were tried, but the latter plan, as involving fewer mechanical difficulties, was adopted for a small trial-instrument of 1¾-inch aperture and 25-inch focal length. With this instrument and method results of a surprising degree of accuracy were obtained—for instance, the latitude of the Harvard College Observatory as determined with it was eventually found to be more accurate than that determined by the fixed instruments of the observatory.

Of the larger instrument subsequently made, which forms the subject of the memoir already mentioned, it is not necessary

for me to say more than that the discussion of the observations made with it shows that it is a most valuable instrument, capable of an accuracy equal to, if not exceeding, that of larger fixed instruments.

One particular point I would like to mention is the marvellous accuracy with which the telescope comes to its true place after each fresh setting. As you no doubt are aware, the observing telescope, and the horizontal axis on which it moves in a vertical plane, are carried by a counterpoised float in a box of mercury, this box in its turn being supported on a vertical axis. The float with the telescope on it is quite free from mechanical connection with the box, the only restraint being that given by two pins working in upright guides to restrain movement sideways.

When the telescope is clamped on its axis to any altitude, the circle it would describe in the heavens if rotated on the vertical axis would be a small circle or almucantar; and the successful use of the instrument depends on the truth with which the telescope can be set to different points on the small circle to which it is at first pointed. Although between each setting the rotation in azimuth sets up a considerable amount of oscillation, the instrument settles down after a short time to a position so nearly the true one that it is difficult to determine its departure from it. In that part of the memoir speaking of this, Mr. Chandler says that after a couple of minutes a mean position of equilibrium is regained within a range of variation so minute that no means exist of measuring it with certainty. In Chap. V. it is experimentally demonstrated that the probable error of equilibrium must lie within one-tenth of a second of arc, corresponding to one hundred thousandth of an inch difference in the two ends of the float.

The consistent way in which this instrument behaves, and the remarkable accuracy with which it takes the true position after a change in azimuth, are due not only to the principle of floatation employed, but also to the peculiar simplicity of construction that this principle allows, for the fresh settings are obtained without the least change of strain in the instrument. In this latter respect it enjoys an advantage over the necessarily heavy meridian instrument with its puzzling flexure; the freedom from mechanical connection with the Earth gives it another hardly less important; while the cost of the respective instruments would be greatly in favour of the simpler form. It seems to me that we have in this instrument capabilities that have not yet been fully appreciated and applied.

It has often occurred to me how the personal character of the designer of an instrument is reflected in the design. We can certainly recognise the same independence of preconceived notions in the almucantar that Mr. Chandler shows in his theoretical discussions; and we find another point of similarity when we compare the speedy way in which the instrument in question takes up and keeps its true position after a few oscillations, with

the manner in which, after a few tentative hypotheses, none of them far from the truth, our medallist found and maintained the real solution of the problem of the variation of latitude.

In this brief review of your medallist's work I think I have said amply sufficient to show you that in computational, observational, and instrumental astronomy, our medallist is in the first rank, and is, indeed, well worthy of the highest honour which it is in our power to bestow upon him.

Dr. Huggins, I place this medal in your hands, as Foreign Secretary, for transmission to Mr. Chandler. Will you express to him our high appreciation of his contributions to astronomy, and our hope that he may be long spared to further enrich our science.

Our regret that Mr. Chandler is unable to be present to-day is tempered by the expectation that some of our Fellows in crossing America for the observation of the Solar Eclipse will be able to personally express this appreciation and hope in a warmer way than can well be done in a letter.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:

President.

A. A. COMMON, Esq., LL.D., F.R.S.

Vice-Presidents.

Capt. W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S.
W. H. M. CHRISTIE, Esq., M.A., F.R.S., Astronomer Royal.
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E. W. MAUNDER, Esq.
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A. M. W. DOWNING, Esq., M.A., D.Sc., Superintendent of the "Nautical Almanac."
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W. H. MAW, Esq.
H. F. NEWALL, Esq., M.A.
Capt. WILLIAM NOBLE.
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E. J. STONE, Esq., M.A., F.R.S., Radcliffe Observer.
G. JOHNSTONE STONEY, M.A., D.Sc., F.R.S.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. MARCH 13, 1896. No. 6

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

James Cavan, M.A., Eaton Mascott Hall, Shrewsbury, and
Thomas Edward Knightley, Clive House, Tulse Hill,
were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

William Banks, Optician, 30 Corporation Street, Bolton, Lancashire (proposed by J. R. Bridson);
Henry Frank Griffiths, Sherwood Villa, Angles Road, Streatham, S.W. (proposed by Rev. W. R. Waugh); and
Alfred Ernest Young, Assoc. M. Inst. C.E., Assistant-Surveyor and Chief Computer, Trigonometrical Survey of Perak, Taiping, Perak, Straits Settlements (proposed by James Simms).

One hundred and sixteen presents were announced as having been received since the last meeting, including, amongst others:—

J. Bauschinger, Untersuchungen über die astronomische Refraction &c., presented by the author; A. Cayley, collected mathematical papers, vol. ix., presented by the Cambridge University Press; Galileo, Opere, Edizione nazionale, presented by the Italian Government; Lick Observatory Contributions, Nos. 4 and 5, presented by the Observatory; nine enlargements from

negatives of the Moon by MM. Lœwy and Puiseux, presented by Dr. Weinek; photographs of the lunar eclipse 1896 February 28, presented by G. J. Newbegin.

On the Systematic Errors of Measures on Photographic Plates.
By H. H. Turner, M.A., B.Sc., Savilian Professor.

(1) In the January number of the *Monthly Notices* the Astronomer Royal and Mr. Dyson gave an account of the work done at the Royal Observatory, Greenwich, in measuring and reducing a number of plates for the Astrographic Catalogue. The material thus available for the study of the accidental and systematic errors of such measures is most valuable, for the number of overlapping plates discussed brings out the power of the photographic method, and also its limitations, in a very clear manner.

(2) The present note is concerned with one section of the paper only, viz., that headed "Systematic Error in the Determination of *a*." It is therein shown that when a S.E. corner of one plate is compared with the N.W. corner of an overlapping plate, the deduced value of the constant a is positive; whereas when a S.W. corner is compared with a N.E. corner, the value of a is negative—a being one of the constants in a pair of linear equations

$$x_2 - x_1 = ax_1 + by_1 + c$$
$$y_2 - y_1 = dx_1 + ey_1 + f$$

which represent the differences between the coordinates on the two plates. Such a systematic error is cumulative, and prevents the stepping from one plate to another with anything like accuracy.

(3) The sources of such an error may be numerous—errors in the réseau or the measuring scale, optical distortion, &c. It is remarked in the paper that as yet no investigation of them has been made. The object of the present note is to consider one possible cause—viz. tilt of the plate. The error noted is small, though it becomes serious by accumulation; and it is possible that a slight want of perpendicularity of the plate to the line joining the centre of the object-glass and the centre of the plate might explain it in a manner developed in the sequel. I know that particular care has been taken to have this adjustment made at Greenwich, but the adjustments of a telescope cannot be examined every day, and possibly this particular adjustment may have been accidentally disturbed at some time. It is in any case advisable to consider the effect of such a disturbance.

(4) It has been shown in previous papers that if the normal

to the plate from the centre of the object-glass cuts the plate in the point (k, l) and not at the centre $(0, 0)$, then the measured coordinates (x, y) will be related to the standard coordinates (ξ, η) in the following manner :

$$x = \frac{(1+a)\xi + b\eta + c}{1 + k\xi + l\eta} \qquad y = \frac{d\xi + (1+e)\eta + f}{1 + k\xi + l\eta}.$$

Where a, b, c, d, e, f, are all small, we have approximately

$$x = \xi - k\xi^2 - l\xi\eta$$
$$y = \eta - k\xi\eta - l\eta^2.$$

(5) Suppose then that we first calculate ξ and η for the known stars from their R.A.s and N.P.D.s, as given by meridian observations, and then compare these standard coordinates with the measured coordinates. If in the first place we assume $k=0$, $l=0$ (*i.e.* that the plate is adjusted for tilt), we solve equations of the form

$$x - \xi = ax + by + c$$
$$y - \eta = dx + ey + f$$

and hence determine a, b, c, d, e, f. But if this assumption of no tilt is false, these deduced values of a, b, c, d, e, f, will be slightly erroneous. The errors will depend upon the positions of the known stars, and we must make some assumption on this point. The best is that the known stars are distributed uniformly over the plate, which is a square of side $4s$ say (where $s=30'$ approximately). Further, it is here assumed that the procedure adopted is to group all the stars in the N. half of the plate, all in the S. half, all in the E. half, and all in the W. half, as mentioned in previous papers.

(6) Now in considering the effect of tilt we may neglect all other errors; and since we may put $x=\xi$, $y=\eta$ in the small terms, we may consider therefore the equations

$$ax + by + c = -kx^2 - lxy$$
$$dx + ey + f = -kxy - ly^2.$$

Integrating these over the N. half of the plate ($x=-2s$ to $x=+2s$, $y=0$ to $+2s$) we get

$$0 \,.\, a + 8s^3b + 8s^2c \,.\, = \frac{32s^4}{3}k - 0 \,.\, l$$
$$0 \,.\, d + 8s^3e + 8s^2f = -0 \,.\, k - \frac{32s^4}{3}l.$$

From the S. half we should get

$$0 \,.\, a - 8s^3b + 8s^2c = -\frac{32s^4}{3}k - 0 \,.\, l$$
$$0 \,.\, d - 8s^3e + 8s^2f = -0 \,.\, k \,.\, -\frac{32}{3}s^4l.$$

Subtracting S. half from N. we get

$$b=0,\ e=0,\ c=-\frac{4s^2}{3}k,\ f=-\frac{4s^2}{3}l.$$

Similarly from the E. and W. halves of the plate we should get

$$a=0,\ d=0,\ c=-\frac{4s^2}{3}k,\ f=-\frac{4s^2}{3}l.$$

The measured coordinates

$$\xi-k\xi^2-l\xi\eta,\quad \eta-k\xi\eta-l\eta^2$$

are thus reduced, after comparison with ξ and η, to

$$\xi-k\xi^2-l\xi\eta+\frac{4s^2}{3}k,\quad \eta-k\xi\eta-l\eta^2+\frac{4s^2}{3}l.$$

(7) Now let another plate have its centre at $(+2s, +2s)$, and suppose its scale the same as that of the former and its orientation correct, and that the theoretical expressions have been applied to reduce the measures upon it to accordance with the measures on the first plate. If there were no error of tilt the coordinates of all stars would now exactly agree, except for accidental errors. But if the agate points against which the plates are brought into position for perpendicularity to the axis of the telescope be not correctly adjusted, there will be a systematic error of "tilt"—the same for both plates. From what precedes it will be seen that the ξ-coordinate of a star on the first plate (A) will now be

$$\xi-k\xi^2-l\xi\eta+\frac{4s^2}{3}k$$

and of the same star on the second plate (B)

$$\xi-k(\xi-2s)^2-l(\xi-2s)(\eta-2s)+\frac{4s^2}{3}k$$

and the residual difference will be

$$\xi_B-\xi_A=s\xi(4k+2l)+2s\eta l-4ls^2.$$

Similarly

$$\eta_B-\eta_A=s\eta(4l+2k)+2sk\xi-4ks^2.$$

Let us now consider plates overlapping the other corners viz.

Plate C centre $(-2s, +2s)$
,, D ,, $(-2s, -2s)$
,, E ,, $(+2s, -2s)$.

The corresponding equations can be easily deduced, and the whole set will be as follows :—

$$\xi_B - \xi_A = s\xi(+4k+2l) + 2s\eta l - 4ls^2$$
$$\xi_C - \xi_A = s\xi(-4k+2l) - 2s\eta l + 4ls^2$$
$$\xi_D - \xi_A = s\xi(-4k-2l) - 2s\eta l - 4ls^2$$
$$\xi_E - \xi_A = s\xi(+4k-2l) + 2s\eta l + 4ls^2$$

$$\eta_B - \eta_A = s\eta(+4l+2k) + 2s\xi k - 4ks^2$$
$$\eta_C - \eta_A = s\eta(+4l-2k) + 2s\xi k + 4ks^2$$
$$\eta_D - \eta_A = s\eta(-4l-2k) - 2s\xi k - 4ks^2$$
$$\eta_E - \eta_A = s\eta(-4l+2k) - 2s\xi k + 4ks^2.$$

(8) To estimate the magnitude of these terms it should be remarked that s is approximately 30′, or ·0087 in circular measure; and if $k=10'$ (*i.e.* if the normal from the centre of the object-glass on to the plate cuts it only 2 réseau intervals away from the adopted centre) we have

$$4ks = \cdot 0087 \times \cdot 0087 \times \frac{4}{3} = \cdot 00010;$$

so that the differences of coordinates on two plates will be represented by terms such as

$$\xi_B - \xi_A = \cdot 00010\xi$$
$$\eta_B - \eta_A = \cdot 00005\xi + \cdot 00005\eta - \cdot 00010s.$$

These coefficients are just of the order of magnitude noticed by the Astronomer Royal and Mr. Dyson in their paper (*Monthly Notices*, lvi. pp. 125, 126).

The case of transformation from S.E. to N.W. corresponds to our transformation from C to A (or A to E); the case of transformation from S.W. to N.E. is that from B to A (or A to D). And we have in the first case

$$a_1 = s(-4k+2l),\ e_1 = s(4l-2k),\ (b+d)_1 = 2s(k-l)$$

and in the second case

$$a_2 = s(4k+2l),\ e_2 = s(4l+2k),\ (b+d)_2 = 2s(k+l).$$

Taking the means of the values given on p. 125 we have

$$a_1 = +\cdot 00011,\ e_1 = +\cdot 00003,\ (b+d)_1 = -\cdot 00003$$
$$a_2 = -\cdot 00012,\ e_2 = +\cdot 00001,\ (b+d)_2 = \cdot 00000$$

and we have thus six equations to determine k and l. Solving by least squares we get

$$2ks = -\cdot 000044,\ 2ls = +\cdot 000009$$

which give the values for a_1, a_2, &c., shown in column C below :

	O.	C.	O−C.
a_1	$+\cdot00011$	$+\cdot00010$	$+\cdot00001$
e_1	$+\cdot00003$	$+\cdot00006$	$-\cdot00003$
$(b+d)_1$	$-\cdot00003$	$-\cdot00005$	$+\cdot00002$
a_2	$-\cdot00012$	$-\cdot00008$	$-\cdot00004$
e_2	$+\cdot00001$	$-\cdot00003$	$+\cdot00004$
$(b+d)_2$	$\cdot00000$	$-\cdot00004$	$+\cdot00004$

the sums of the squares of the quantities being reduced in the proportion 284 to 62.

(9) The table which follows on p. 126 of the above paper gives the results when an overlapping plate is used to connect two plates in the same zone ; thus :

$$\begin{aligned}\xi_C-\xi_B&=(\xi_C-\xi_A)-(\xi_B-\xi_A)\\&=-8ks\xi-2ls\eta+8ls^2\end{aligned}$$

from above ; and

$$\eta_C-\eta_B=0\xi-4ks\eta+8ks^2.$$

With the above values of k and l we should have for the expression of these residuals

$$\begin{aligned}a&=-8ks=+\cdot00018 \quad & b&=-2ls=-\cdot00001\\ d&=0 & e&=-4ks=+\cdot00009.\end{aligned}$$

The mean value of a given in the paper from seventeen plates is $+\cdot00021$. The values of e are not given in the paper, but were kindly furnished by the Astronomer Royal, on application, for all plates but one pair (2136–2227). Omitting this from a also we find mean values

$$a=\cdot00020,\quad e=-\cdot00004$$

and the observed and calculated values of e thus differ by $\cdot00013$. This certainly throws some doubt on the reality of the "tilt" as a cause of the errors under discussion, unless there is some numerical mistake. But there is no doubt of the importance of this adjustment for "tilt," if plates are to be connected with one another in this way ; and it appears from what precedes that such an error should, if sensible, be detected in the comparison of plates with overlapping plates by means of the criterion

$$a=2e.$$

(10) In conclusion, I venture to make a simple suggestion. Why should each region be photographed on a different plate? It would strengthen the determination of systematic errors immensely if several regions were photographed on the same plate without disturbing the telescope very seriously, or the plate in its holder at all. The stars of different regions might be identified by making the displacements from the 6m to the 3m exposure in different directions, or of different magnitudes, and the cases where stars of one region interfered with those of another would be rare. To have more stars on one plate would make it easier to measure, and there would be economy in many ways—of time in changing plates and developing, and of expense in actual plates and reproduction if any. We are trying this method at Oxford to see how it works.

Note on Professor Turner's Paper on the Systematic Errors of Measures of Photographic Plates. By W. H. M. Christie, M.A., F.R.S., and F. W. Dyson, M.A.

Professor Turner points out that the systematic difference in the value of the constant *a* on the two halves of the photographic plates taken at the Royal Observatory, referred to in a paper in the *Monthly Notices* for January, may be due to a tilt of the

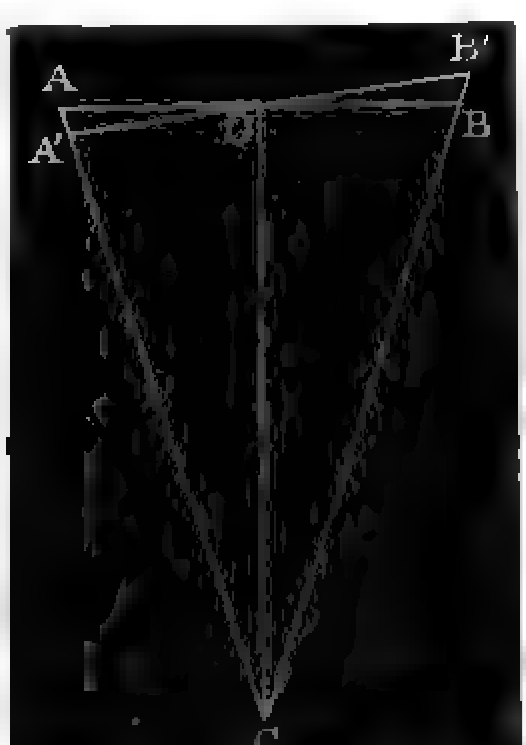


plate. It is easily seen geometrically that a tilt would have this effect. In the diagram O is the centre of a plate, C the centre

of the object-glass, and A B : A′ B′ are the positions of two stars on plates without and with a tilt.

Let the tilt, $AOA' = i$, and let

$$\angle ACO = \angle BCO = a.$$

If the tilt be uncorrected for, there will be an apparent scale correction of

$$\frac{OA}{OA'} - 1$$

for the star A′, and of

$$\frac{OB}{OB'} - 1$$

for the star B′.

Now

$$\left.\begin{aligned} \frac{OA}{OA'} - 1 &= \frac{\cos(a-i)}{\cos a} - 1 = +\sin i \tan a \\ \frac{OB}{OB'} - 1 &= \frac{\cos(a+i)}{\cos a} - 1 = -\sin i \tan a \end{aligned}\right\}$$

and

The difference of these is $2 \sin i \tan a$, and if a be taken as 30′, this$=\cdot 0174 \sin i$. Equating this to ·00010, the value of the discordance found on the Greenwich plates, we find that $i = 20'$.

It seemed almost impossible that there should have been any error of this magnitude, and reference to the adjustment book showed that previous to 1894 September 10 the tilt was about 5′. On 1894 September 17 the tilt was readjusted by Mr. Criswick and reduced to between 1′ and 2′. The tilt was found to be the same on 1896 March 5, when it was measured by Mr. Dyson and Mr. Hollis.

An independent proof that the discordance in question is not caused by tilt is furnished by Professor Turner's criterion, that if it were there would be a discordance in e of the same sign and half the amount of the discordance in a. Comparison of the following figures shows that this is not the case.

The following table is a copy of that on p. 126 of the paper in the January number of the *Monthly Notices* above referred to, with the corresponding values of e added for comparison with those of a:—

Zone. °	Nos. of Plates.	Difference of α	Means.	Difference of δ.	Means.
65	1274–534	+ ·00023	+ ·00026	+ ·00013	− ·00007
	534–426	+ ·00036		− ·00014	
	426–2270	+ ·00032		− ·00033	
	2280–535	+ ·00013		+ ·00006	
66	443–444	+ ·00026	+ ·00019	+ ·00019	− ·00005
		+ ·00034		+ ·00028	
	444–1236	+ ·00015		− ·00024	
	1236–2290	+ ·00007		− ·00018	
	2290–2238	+ ·00037		− ·00028	
	2279–2308	+ ·00007		− ·00006	
67	2288–2289	+ ·00012	+ ·00019	+ ·00002	+ ·00001
	2289–2251	+ ·00024		+ ·00005	
	2251–1416	+ ·00020		− ·00005	
68	2136–2227	+ ·00039	+ ·00029	+ ·00058	+ ·00010
	2227–1397	+ ·00023		+ ·00021	
		+ ·00013		+ ·00001	
	1397–2306	+ ·00006		− ·00016	
		+ ·00024		+ ·00002	
	2057–2058	+ ·00045		− ·00006	
69	1323–2291	+ ·00004	+ ·00004	− ·00002	− ·00002

The plates whose numbers are less than 2227 were taken before the alteration in the adjustment for tilt on 1894 September 17. Examination of the figures in the above table shows that this did not sensibly alter the value of the discordance in question.

A Graphical Method of Solving Kepler's Equation.
By H. C. Plummer.

(*Communicated by H. H. Turner.*)

The prominence which Dr. T. J. J. See in a recent paper published in the *Monthly Notices* gave to the Waterston-Dubois method of solving Kepler's Equation makes it appear likely that another graphical method may have some interest. The question of authorship to which that paper gave rise causes hesitation in claiming originality; but the method which is here described has not, so far as I am aware, been published previously. It is proposed to show a way of finding an approximate solution of the

equation $E - M = e \sin E$ corresponding to a given value of M, e being $\nless \cdot 1$ and $\ngtr \cdot 9$, and also to show how the error in the value of E so found may be discovered very simply by graphical means.

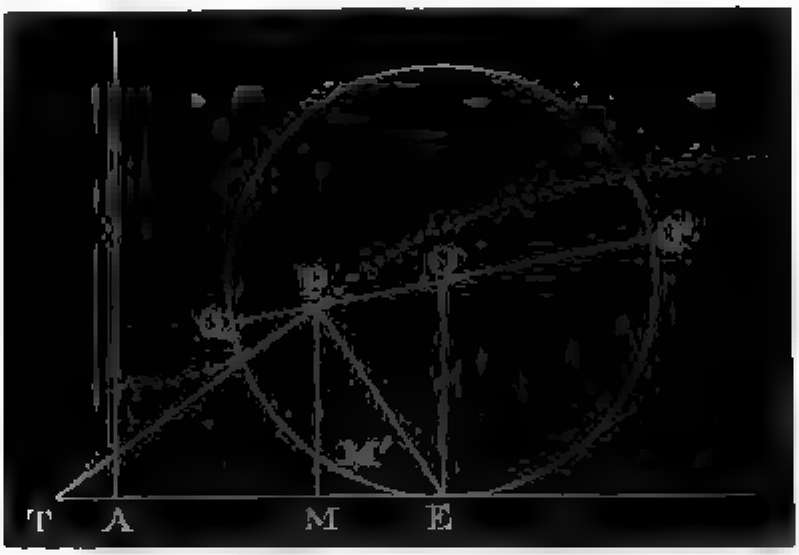


FIG. 1.

Let a circle (centre O) of unit radius *roll* along a straight line, and let a radius OQ be divided at P in the ratio $e : 1 - e$. Let A be the point where Q was originally on the line, M the foot of the ordinate through P, and E the point of contact of the circle at the instant.

Then

$$AM = AE - ME = \text{arc } QE - OP \sin POE.$$

Hence if AM = M, since the radius is of unit length, and OP = e, arc QE = E. But if M′ is the point on the circle such that QM′ = AM = M, M′ was formerly coincident with the present position of M.

It thus appears that we may take an ordinary semicircular protractor, marking the point P which divides the radius through the zero reading in the ratio $e : 1 - e$. The division will be facilitated if the radius has a convenient scale marked along it. The protractor is placed in contact with a straight ledge at a fixed point, so that the reading at this point is M. The instrument must then be rolled along the ledge until the point P comes on the perpendicular to the ledge at the fixed point. The reading at the new point of contact is the required angle E.

The method just described has the great advantage of possessing the utmost simplicity of construction, requiring no specially prepared curve, and being practically instantaneous in application. On the other hand, it is only possible to obtain very roughly approximate results on account of the difficulty of avoiding an error, amounting to a considerable fraction of a degree, in reading off the point of the circumference in contact with the ledge. It is therefore necessary to slightly modify the method

in order to get more refined approximations. For this purpose it must be noticed (1) that since (fig. 1) the arc QE=AE, the readings may be taken along, or parallel to, the base, instead of round the circumference; and (2) that since OE is an ordinate, the abscissa of O may be read instead of the abscissa of E.

Let a board be covered with millimetre paper, one set of lines being parallel to a straight ledge at the side of the board. Let the length of the base (corresponding to 180°) be 450 mm. (say), so that 2·5 mm. correspond to a degree. Now make a semicircle of some material, stout cardboard, for instance, whose curved boundary is also 450 mm., so that its radius is

$$\frac{450}{\pi}\text{ mm.} = 143{\cdot}24\text{ mm.}$$

If the disc is covered with millimetre paper, with one set of lines perpendicular to one of the bounding radii, it is easy to find the point P which divides the radius in the ratio $e : 1-e$ very accurately. If the semicircle is now placed with this radius perpendicular to the base at one extremity, and then rolled along the base until P has the abscissa M (the extremity of the base being the origin of coordinates), the abscissa of the centre is E, and can be read off with no greater error than 0°·1, provided *no slipping* of the semicircle has been allowed to take place.

Let E_0 be the approximation to E thus found, and let $M_0 = E_0 - e \sin E_0$. Hence $\Delta M = M - M_0$ can be found at once.

Now

$$\begin{aligned} E &= f(M) = f(M_0 + \Delta M) \\ &= f(M_0) + \Delta M f'(M_0) + \frac{(\Delta M)^2}{2} f''(M_0) + \dots \\ &= E_0 + \frac{\Delta M}{1 - e\cos E_0} - \frac{(\Delta M)^2}{2} \cdot \frac{e \sin E_0}{(1 - e\cos E_0)^2} \cdot \frac{1}{1 - e\cos E_0} + \dots \end{aligned}$$

Hence neglecting small quantities of order higher than the first,

$$E - E_0 = \Delta E = \frac{\Delta M}{1 - e\cos E_0}.$$

Now $1 - e\cos E_0$ can be read off at once, for referring to fig. 1,

$$1 - e\cos E_0 = OE - OP\cos POE = PM$$

and it is therefore only necessary to read off the ordinate of P. The facility with which this correcting factor can be found seems to show that this method may be of considerable value in those cases where a second approximation by graphical means is desired. In practice it will probably be found best to treat the new approximation to E in the same way if approximations still closer are desired. It is, however, perhaps worthy of note that the calculation of the term in the above series involving a small

quantity of the second order is made very simple by the graphical method. For suppose the perpendicular at P to PE meets the base in T (fig. 1); then

$$TM = PM^2/ME = (1 - e\cos E)^2/e\sin E$$

and the coefficient need only be estimated roughly, since it multiplies a very small quantity.

The roulette traced by P is of course a prolate trochoid, to which PE is the normal at P, and TM is a sub-tangent. The instant when P falls on a given ordinate is always well marked, since the maximum inclination to the base of the tangent to the trochoid is $\sin^{-1}e$. This fact, which can be seen very easily, makes it clear that the error in reading off E is sensibly the same for all values of M, as well as for all values of e, for $\sin^{-1}e$ never exceeds 65°. This is an important point in favour of what may be called the trochoid method, for under certain circumstances the use of the curve of sines cannot give a very good result on account of the approach to parallelism of the curve and the line $x-ey=M$ at the point of intersection.

The method which has been here described is fully as general in its application as that of Waterston, and though I have had no opportunity of making an extended practical use of either method for the purposes of comparison, there seems to be no reason to anticipate any other than a successful trial for the trochoid method. The *slipping* of the disc along the base is the one thing to be feared, but this can be avoided by careful use and by giving a rough edge to the disc. Besides being equally well adapted to cases in which only rough approximations are needed, or in which the highest degree of accuracy attainable by graphical means is required, the trochoid method promises to be greatly superior when a limited use only is expected, in which case the trouble of constructing a reasonably accurate curve of sines would render the older method quite impracticable.

Hertford College, Oxford:
1896 *March* 9.

Observations of Comet a 1896 (Perrine-Lamp) made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1896. d h m s		m s	s		″	″			h m s	° ′ ″	
Feb. 25 7 2 57	A.C.	+0 27·63	+0·05	9·6496	−14 8·6	−0·7	0·8163	3	22 1 17·47	50 35 27·0	*a*
25 7 17 40	,,	−0 5·31	−0·01	9·6384	+ 2 33·7	+0·1	0·8298	6	22 1 38·00	50 33 3·2	*b*
Mar. 1 7 30 46	B.	+0 23·68	−0·01	9·7641	−13 34·8	−0·2	0·6232	4	0 18 4·12	39 9 12·6	*c*
1 8 2 46	,,	+0 32·17	0·00	9·7565	+12 27·3	+0·2	0·6760	6	0 18 47·87	39 8 0·3	*d*
2 9 25 41	D.	+1 26·15	0·00	9·7390	+ 1 50·4	+0·1	0·7679	4	0 44 11·14	38 29 38·8	*e*
2 9 27 27	B.	+1 29·74	0·00	9·7394	+ 2 16·0	+0·1	0·7709	2	0 44 14·73	38 30 4·4	*e*
4 10 32 31	H.	−1 41·90	+0·01	9·7125	− 7 9·1	−0·4	0·8070	5	1 26 35·94	38 15 21·2	*f*
4 10 32 31	,,	−2 30·69	+0·01	9·7125	− 6 29·3	−0·4	0·8070	5	1 26 35·84	38 15 22·6	*g*

Notes.

The observations are corrected for refraction but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

Feb. 25.—Comet faint and difficult to observe owing to bright moonlight and slight haze.

Mar. 1.—Comet very bright, with nucleus.

The initials D., H., A.C., B., are those of Mr. Dyson, Mr. Hollis, Mr. Crommelin, and Mr. Bryant respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1896·0. h m s	Assumed N.P.D. 1896·0. ° ′ ″	Authority.
a	W.B. (2) xxi. 1499–500	22 0 51·00	50 49 30·9	Lund Astr. Gesell. Zones, 295. 300.
b	B.D. + 39°, No. 4751	22 1 44·55	50 30 24·0	,, ,, 41, 51, 531.
	O.A. (N.), 281	0 17 41·89	39 22 56·0	Cambridge (U.S.) Astr. Gesell. Catalogue.
d	O.A. (N.), 294	0 18 17·17	38 55 41·3	,, ,, ,, ,,
e	Lalande, 1284	0 42 46·33	38 27 58·9	,, ,, ,, ,,
f	B.D. + 51°, No. 334	1 28 18·82	38 22 44·6	,, ,, ,, ,,
g	Groombridge, 340	1 29 7·51	38 22 6·3	Greenwich Observations, 1887, 1890, 1891, Paris and Cambridge (U.S.) Catalogues.

Observations of Comets made at the Royal Observatory, Blackford Hill, Edinburgh.

(Communicated by the Astronomer Royal for Scotland.)

The following observations were made by Dr. J. Halm with the 15-inch Dunecht Refractor and the wire micrometer, except the second observation of December 11, which was made by Professor Copeland.

The adopted position of the new Transit House is

Lat. $+55^\circ\ 55'\ 28''\cdot0$.

Long. West $12^m\ 44^s\cdot2$.

The 15-inch Refractor stands $0^s\cdot2$ east of the Transit House.

☄ *Swift* (1895 *Aug.* 20).

1895.	M.T. Edinburgh.	(☄ − ✱) Δα.	(☄ − ✱) Δδ.	No. of Comp.	α App.	Log pΔ.	δ App.	Log pΔ.	Reduction to App. Pl.		✱
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Oct. 16	11 3 49	−0 34·02	−2 39·7	18, 7	1 26 34·70	8·786n	+3 40 24·0	0·848	+3·97	+27·3	1
17	9 45 9	−0 28·46	−5 4·0	36, 12	1 26 40·27	9·214n	+3 37 59·7	0·851	+3·98	+27·3	1
18	10 52 41	−0 33·26	...	24, 0	1 26 45·60	8·788n	...	...	+3·99		2
18	10 59 6	...	+2 17·5	0, 9	...	...	+3 35 36·7	0·849		+27·3	2
					☄ *Perrine* (1895 *Nov.* 16).						
Nov. 18	18 13 29	+7 27·78	−3 52·2	9, 3	13 48 15·32	9·442n	+0 48 18·7	0·866	+1·90	−17·0	3
					☄ *Brooks* (1895 *Nov.* 21).						
Dec. 7	9 8 48	−2 42·30	...	15, 0	8 21 36·06	9·644n	...	...	+5·63	...	4
8	11 13 11	...	−1 16·8	0, 3	...	...	+45 2 55·3	0·513	...	−13·5	5
9	9 55 12	+1 42·01	−1 28·3	18, 9	7 57 29·81	9·683n	+48 36 38·6	0·572	+6·51	−12·0	6
9	11 57 11	+1 16·17	+2 29·0	10, 5	7 56 23·71	9·527n	+48 55 14·2	0·303	+6·53	−11·9	7
11	8 39 7	−2 49·88	+0 3·8	20, 10	7 30 9·03	9·762n	+54 59 41·7	0·567	+7·43	− 9·2	8
11	9 56 12	−0 41·20	+6 37·0	4, 4	7 29 19·74	9·717n	+55 9 17·6	0·370	+7·45	− 8·8	9
11	11 34 16	−1 41·81	−5 10·9	12, 6	7 28 17·15	9·560n	+55 21 7·0	9·976	+7·51	− 8·9	10
13	11 2 27	−1 7·95	+4 23·9	14, 7	6 56 2·04	9·600n	+60 21 24·9	9·088	+8·50	− 3·6	11
20	8 33 57	+0 45·76	+5 18·9	10, 8	4 49 46·78	9·711n	+68 28 38·4	0·049n	+10·05	+19·7	12

Mean Places of Comparison Stars.

No.	α 1895·0.	δ 1895·0.	Authority.
	h m s	° ′ ″	
1	1 27 4·75	+3 42 36·4	A.G.Z. Albany.
2	1 27 14·87	+3 32 51·9	" "
3	13 40 45·64	+0 52 27·9	" "
4	8 24 12·73	+40 34 37·1	A.G.Z. Bonn.
5	8 10 23·53	+45 4 25·6	" "
6	7 55 41·29	+48 38 18·9	" "
7	7 55 1·01	+48 52 57·1	" "
8	7 32 51·48	+54 59 47·1	A.G.Z. Hels. Gotha.
9	7 29 56·49	+55 2 49·4	Comp. with A.G.Z. Hels. Gotha, 5177.
10	7 29 51·45	+55 26 26·8	A.G.Z. Hels. Gotha.
11	6 57 1·49	+60 17 4·6	" "
12	4 48 50·97	+68 22 59·8	A.G.Z. Christiania.

Notes.

Comet *Swift* was always very faint and without a distinct nucleus.

Comet *Perrine* bright, with a nucleus of about sixth magnitude and a tail extending due north.

Comet *Brooks* exceedingly faint and of irregular outline; very difficult to observe on account of its want of any precise nucleus.

Observations of Comets made at the Royal Observatory, Blackford Hill, Edinburgh (15-inch Refractor and Wire Micrometer).

(Communicated by the Astronomer Royal for Scotland.)

☄ *Perrine* (1895 Nov. 16).

1896.	M.T. Edinburgh. h m s	(☄−✱) Δα. m s	(☄−✱) Δδ. ′ ″	No. of Comp.	α App. h m s	Log pΔ.	δ App. ° ′ ″	Log pΔ.	✱
Feb. 23	17 44 38	−0 39·34	−0 46·1	14, 6	19 46 34·26	9·442n	+ 0 21 58·2	0·860	1
Mar. 1	16 36 38	+1 31·12	−0 57·3	21, 7	19 46 52·84	9·484n	+ 2 15 38·3	0·858	2
3	16 30 31	−0 22·14	+6 49·8	36, 12	19 46 48·69	9·483n	+ 2 48 23·2	0·857	3
9	16 29 19	−2 31·90	+2 36·3	36, 12	19 46 9·59	9·460n	+ 4 27 24·6	0·851	4

☄ *Perrine-Lamp* (1896 Feb. 14).

1896.	M.T. Edinburgh. h m s	(☄−✱) Δα. m s	(☄−✱) Δδ. ′ ″	No. of Comp.	α App. h m s	Log pΔ.	δ App. ° ′ ″	Log pΔ.	✱
Mar. 3	*10 14 55	−1 58·36	−5 39·7	21, 7	1 6 59·69	9·670	+51 45 16·1	0·807	5
3	17 15 31	+1 43·86	−1 31·3	21, 7	1 12 57·53	9·562n	+51 46 26·4	0·867	6
5	9 14 32	−0 34·94	+7 16·6	21, 7	1 43 12·65	9·723	+51 34 27·8	0·699	7
5	9 46 46	−0 41·95	+8 37·0	18, 6	1 43 34·57	9·711	+51 34 8·2	0·744	8
6	7 7 30	+0 39·00	+5 2·2	6, 2	1 57 23·96	9·672	+51 18 22·0	0·443	9
6	10 39 15	+1 59·95	+3 21·4	18, 6	1 59 32·59	9·681	+51 15 10·8	0·793	10
8	11 7 20	+4 23·22	−3 40·2	18, 6	2 25 24·93	9·663	+50 25 45·8	0·808	11
9	7 39 51	−0 56·62	+0 58·8	24, 8	2 34 37·93	9·667	+50 2 25·6	0·483	12
9	9 10 37	−1 12·56	+3 49·8	24, 8	2 35 16·69	9·711	+50 0 38·4	0·653	13
9	10 26 33	+0 14·41	−2 17·5	5, 5	2 35 48·96	9·695	+49 59 9·3	0·758	12

Mean Places of Comparison Stars.

No.	α 1896·0.	δ 1896·0.	Reduction to app. place.		Authority.
	h m s	° ′ ″	s	′	
1	19 47 13·64	+ 0 22 56·5	−0·04	−12·2	Schj.
2	19 45 21·62	+ 2 16 48·6	+0·10	−13·0	Bonn. Obs. 1855.
3	19 47 10·66	+ 2 41 46·5	+0·17	−13·1	A.G.Z. Albany.
4	19 48 41·23	+ 4 25 1·9	+0·26	−13·6	" "
5	1 8 59·21	+51 50 43·1	−1·16	+12·7	A.G.Z. Camb. Mass.
6	1 11 14·81	+51 47 44·9	−1·14	+12·8	" "
7	1 43 48·44	+51 26 56·4	−0·85	+14·8	" "
8	1 44 17·37	+51 25 16·4	−0·85	+14·8	" "
9	1 56 45·69	+51 13 4·3	−0·73	+15·5	" "
10	1 57 33·37	+51 11 33·9	−0·73	+15·5	" "
11	2 21 2·21	+50 29 18·6	−0·50	+16·4	" "
12	2 35 34·90	+50 1 9·9	·0·35	+16·9	A.G.Z. Bonn.
13	2 36 29·59	+49 56 31·7	−0·34	+16·9	" "

Comet Perrine very faint on March 3 and 9.

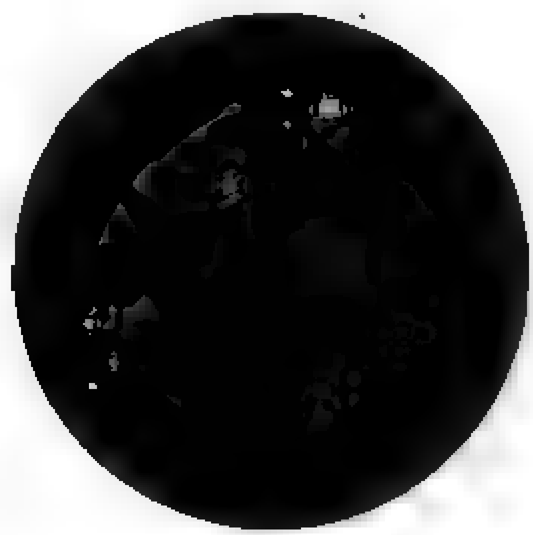
Comet Perrine-Lamp bright and highly condensed towards the centre, but without a distinct nucleus.

The observations were made by Dr. J. Halm, except the last measure, on March 9, which was made by Professor Copeland.

Royal Observatory, Blackford Hill:
1896 *March* 12.

Discovery and Observations of Comet Brooks (d 1895).
By W. R. Brooks.

I have the honour to communicate to the Society some notes on the discovery and observations of my comet of November 21. While sweeping the south-eastern heavens with the 10-inch equatorial, at about 14 hours, standard 75th meridian time, I picked up a large nebulous mass, which I at once recognised as new.



Discovery field. Comet Brooks.

The discovery place was R.A. $9^h\ 51^m\ 50^s$, Decl. S. 17° 40′.

I give herewith a chart of the discovery field.

In a few minutes after securing the discovery position the sky, which up to that time had been remarkably clear, became clouded, but fortunately not before I had detected motion, which proved to be rapid and in a northerly direction. For over an hour not a star was to be seen in any part of the heavens, but by the driving-clock the telescope was kept on the object, hoping for a break in the clouds. This came in about an hour, and the direction of the comet's motion was ascertained beyond a doubt. The morning was intensely cold, the thermometer standing at 10° above zero, and when a little later I went down to the telegraph office, about one mile distant, to announce the discovery, it was snowing furiously.

Nearly a week of storms and cloudy weather followed, so that it was not until the sixth morning after the discovery that I was able to secure another observation of the comet.

It had in this interval, with its rapid motion of three degrees daily, moved over a great distance, so that on the morning of November 27, $15^h\ 40^m$, it was observed in R.A. $9^h\ 29^m\ 30^s$; Decl. N. 0° 47′; and the comet appeared larger and brighter than at discovery.

The following observations have since been made :—

November 28, $17^h\ 30^m$; R.A. $9^h\ 23^m\ 55^s$; Decl. N. 3° 12′. The comet is slightly brighter than it was yesterday morning.

December 12, $9^h\ 30^m$ (evening observation) ; R.A. $7^h\ 9^m\ 30^s$; Decl. N. 58° 19′. Considerably fainter. The comet is now circumpolar, and evening observations are possible.

December 13, 7^h ; R.A. $6^h\ 55^m\ 20^s$; Decl. N. 60° 23′. Large, but pretty faint.

December 16, 9^h ; R.A. $5^h\ 58^m\ 10^s$; Decl. N. 65° 30′. Faint.

The comet has at all times appeared large, round, and with very slight central condensation.

Smith Observatory, Geneva, N.Y., (U.S.A.) :
1895 *December* 21.

Elliptical Orbit Elements of Comet b 1894 (*Gale*). By Rev. Thomas Roseby, M.A., LL.D.

The following elements are based on four normal places, derived, the first two from Mr. Tebbutt's Windsor observations only, the last two from observations made at Windsor (N.S.W.), Melbourne, Liverpool, Greenwich, Lyons, Besançon, and Dudley (U.S.A.). The time interval between the extreme normal places is 78 days. I have to express my indebtedness to Mr. J. Tebbutt, F.R.A.S., of Windsor, Mr. R. T. A. Innes, F.R.A.S., and Mr. C. J. Merfield, of Sydney, for help without which the labour of this computation would hardly have been undertaken. The residuals for the middle places seem fairly satisfactory. The orbit elements indicate a period for the comet of 1001·18 years. The elements are :

Comet b 1894 (*Gale*).

τ 1894 April 13·393265 G.M.T.

π	170° 35′ 52″·42	Mean equinox 1894·0.
☊	206 24 11·90	Mean equinox 1894·0.
i	86 58 55·73	Mean equinox 1894·0.
log q	9·9925685	
log e	9·9957130	

Motion direct.

The residuals for the mean places are :

$$d\lambda_{,} \cos \beta_{,} = -0''\!\cdot\!59$$
$$d\beta_{,} = -1\cdot64$$
$$d\lambda_{,,} \cos \beta_{,,} = +1\cdot48$$
$$d\beta_{,,} = +1\cdot27$$

It is to be remarked, however, in respect to this comet:

1. That the high inclination of the comet's orbit (nearly 87°) necessarily introduces an element of uncertainty into its heliocentric coordinates on the plane of the ecliptic.

2. That the very slow movement of the comet during its earliest observations introduces a similar element of uncertainty into the *times* of these observations. Thus the movement of the comet from April 3 to April 8 was so slow that it amounted in R.A. to only about 1″·0 in 26 seconds of time, and in declination to only about 1″·0 in 750 seconds of time.

From these causes I shall not be surprised to find a considerable discrepancy between the above elements and those of the final definitive orbit, which orbit must itself, however, so it seems to me, be subject, more or less, to the same elements of uncertainty.

Parsonage, Marrickville, New South Wales:
1896 January 1.

Occultation of Jupiter, 1893 February 20 as seen at the Durham University Observatory.

(*Communicated by the Director.*)

The following are Mr. H. J. Carpenter's notes:—

Jupiter was found quite easily about 2 P.M., though it was faint. Unfortunately it clouded before the disappearance of the planet, and remained so till just before the reappearance, when the following observations were made:—

	G.M.T. h	m	s
First seen, well off Moon's disc	3	7	26
Bisected	3	8	11·0
Last contact	3	9	40·7

It was observed with the 6-inch equatorial with a power of 100.

The impression I formed was that the last contact was late, probably 2^s to 4^s. Some seconds before this time the Moon's limb had the appearance of being bulged in, or a piece cut out. This occurred so rapidly, and I was watching for "last contact," that I could not give much attention to it.

The sky was very hazy and *Jupiter* faint, but the Moon's limb was fairly well defined.

After the last time given *Jupiter* appreciably separated from the Moon.

Longitude 6^m $19^s{\cdot}7$ W. of Greenwich.

Fireball of 1895 *November* 22, 6^h 50^m. By W. F. Denning.

Having recently received two additional observations of this brilliant object, I have reinvestigated its path with fairly satisfactory results. It appeared at an epoch which is unusually productive in phenomena of this kind, and there is no doubt that the recent fireball furnishes another fine Taurid to the already numerous series recorded in past years.

I have observations from eight places—viz. Brighton, Bristol, Ealing (W.), Eastbourne, Ipswich, Isle of Wight, Rickmansworth (Herts), and Torquay—but at Bristol, Ealing (W.), and Ipswich the sky was overcast, and the observers could record no more than the sudden and intense illuminations of the firmament caused by the meteor.

At Bristol I thought the light was greater than the full Moon could have occasioned. At Ealing (W.) Mr. R. T. Lewis says "the effect was similar to that which might have been produced by the explosion of a large magnesium shell sufficiently brilliant to illuminate the entire sky." At Ipswich Mr. A. Southgate remarks that "the sky, which was densely overcast, was suddenly and completely illuminated by a brilliant bluish light which appeared to penetrate the clouds. The effect was nearly equal to that of the Moon."

At other places where the meteor itself was seen its brightness was remarkable. At Brighton Mr. A. Stanley Williams noted that it lit up the whole country to the north. At Torquay Mr. C. W. Priestley's attention was called to the meteor by a strong light behind him, which he at first thought to be due either to the search-light of a vessel or a magnesium shell. At the Isle of Wight Capt. S. G. Horton, R.A., says "the meteor commenced as a brilliant white flash, as of a magnesium flash-light, and then followed yellow, red, and green in quick succession, a long streak of whitish light coming out from the main body and vanishing. A glow of yellow light remained where the first flash occurred for about 30 seconds and gradually died away."

Several of the observers noted that the fireball was brightest in the first half of its course, and that from the place of its greatest outburst a fragment shot in the same direction, several degrees further No detonation was heard I have worked out the following details of the path :—

Fireball 1895 *November* 22.

Height when first observed	34 miles
Over	The Nore, river Thames
Height of end of brilliant part of course ...	22 miles
Over	Tilbury
Height at final extinction	17 miles
Over	Greenwich
Earth point	Reading

Real length of observed path	45 miles
Velocity	22 miles per second
Radiant point	$58° + 22°$
Direction of flight...	East to west
Inclination of descent	26°

Very large meteors from *Taurus* are often seen in November, especially during the first week of that month and between the 20th and 23rd. Fireballs appeared in 1865 and 1884, on November 21, and in 1891, on November 22, several brilliant Taurids were visible in the evening sky, and "at Ramsgate were supposed to be rockets fired by the North Sandshead lightship. The lifeboat at once put to sea. A heavy fog prevailed, and it was thought that a vessel had stranded on the Goodwin Sands, but on returning the coxwain reported that the lightship men had only observed two meteorites falling." In 1877 on November 23 two brilliant Taurids were seen. The radiant is at about $63° + 22°$, and I determined it from ordinary shower-meteors in three years as follows :—

		Meteors
1876 November 20	$62° + 22°$	11
1880 November 27	$63 + 21$	8
1886 November 29–December 1	$64 + 23$	6

Earlier in November the radiant appears to be a few degrees west of this. In 1896 on November 2 I witnessed a shower of 17 Taurids from $55° + 9°$, which is fully 15° S.S.W. of the position of the radiant in the last ten days of November.

Bristol 1896 *March* 5.

Note on a Curious Light (*the Zodiacal Light?*) *as seen at Oxford*, 1896 *March* 4. By H. H. Turner, M.A., B.Sc., Savilian Professor.

The evening of 1896 March 4 was brilliantly fine at times. After observing the transit of 6 *Cancri* (R.A. 7^h 57^m), Mr. F. A. Bellamy, assistant in the University Observatory, went out to look at the sky, and his attention was immediately caught by what seemed to be the tail of a very bright comet in the west. He had often observed the zodiacal light in Oxford, but this appearance struck him as quite unfamiliar. He promptly brought out a 3-inch telescope to examine the object, but detected nothing definite; the faint stars showed distinctly through the light. After a minute or two he concluded that it must be an extraordinary apparition of the zodiacal light, which conclusion was confirmed by the position of the object, the direction passing nearly through the *Pleiades*, and the highest point being at an altitude of about 12°. He came up to the transit room to call my attention to it, and found me observing a transit of *Jupiter* (R.A. 8^h 9^m). After this was concluded we went together to look at the phenomenon, but the light had then

become much fainter, though still brighter than Mr. Bellamy remembered to have ever seen the zodiacal light. It was fading rapidly, and within a few minutes was no longer very noticeable. The above transits fix the times with considerable accuracy as follows :—

	h m	
Light first seen	9 14	G.M.T.
Much fainter...	9 26	„
So faint as not to be noticeable	9 30	„

These times seem quite inconsistent with the idea of the light disappearing by *setting* rather than by *fading* ; and, though there were thin streaks of cloud near the horizon, these did not seem to cause the disappearance. There was no motion apparent.

An intermittent watch was kept on the sky till after midnight, but the light was not again noticed, though auroral light and streamers were seen in the north. It is quite possible that the light seen in the west was an auroral display. The evening was more cloudy later.

Besides the extraordinary brilliancy of the light the concentration of it along the axis of the cone (assuming it to be really the zodiacal light) was remarkable, suggesting at first nothing so much as the tail of a comet as bright as that of 1882. The width was estimated by Mr. Bellamy at barely 1° (two diameters of the Moon), and though I did not see it at its brightest my impression would accord with this. The edges were comparatively well defined, and did not present the gradual fading off usually seen in the zodiacal light. It may be remarked that there is some glare from gas lamps in that quarter of the sky as seen from the University Observatory, and much more now than in past years.

On March 5 Sir W. J. Herschel, who had also seen the light at Littlemore, about 2½ miles away, came over to Oxford to make inquiries. He had independently taken the light for the tail of a comet—a fact which gives perhaps the best idea of its appearance.

Sir W. J. Herschel had independently written out his observations in a short note, which I here add *in extenso*.

"*The Zodiacal Light—or is it not a Comet?*

"I have never seen the zodiacal light in England decidedly well. I have seen it elsewhere often enough to know its appearance, and it has always been a fairly evenly distributed light over a large area, fainter of course at the edges, and rather brighter towards the base centre, but not at all strikingly so. I have also seen fine comets. It seems almost impossible to compare such a comet in the open sky with what I know of the appearance of the zodiacal light.

"At 7.35 I left Mr. Sankey's door to walk home: it faces north-westerly. I noticed light in the sky, studied it, and concluded that it must, by its inclination and limits, reaching up nearly to the *Pleiades*, be the upper part of the zodiacal light.

The lower part was hid in a bank of clouds, but the oval tilted outline was apparent enough to *my* eye to leave no doubt that it was the zodiacal light. I called Sankey out; we went into the dark to see it. He thought it was the afterglow of the Sun, but it was too late for that.

"As I came out of the gates I drew the attention of two residents passing by to it. They agreed that the Sun was much too long set, and that it sloped to the left, and was not a level arch. I fixed the slope by a straight edge through β and γ *Andromedæ*, and made the axis of the light parallel to this line.

"I then went home, and at 8.55 received a message from Mr. Sankey to come back and see 'the strange light.' I went back to the railway bridge, and then, to my intense surprise, saw a splendid 'comet' plunging head foremost into the distant trees exactly in the axial line of the zodiacal light, against a faint, clear sky, except that its upper end was lost in a thin, long, level cloud, which lay about—I speak by memory—two-fifths of the height of the *Pleiades* above the horizon.

"There was no room whatever for hesitation. Whether the zodiacal light had been there or not (and at this hour *there was no trace left* of what I had seen before at a quarter to eight), this was a *comet*.

"Its shape was as below:—

Supposed zodiacal light as seen 1896 March 4, 9 P.M.,
by Sir W. J. Herschel.

"The dotted line may be taken to show the area the zodiacal light had occupied. Spectators gathered, but in about ten minutes the mist obscured all but the upper one-third.

"The axis proved exactly parallel to the same two stars of *Andromeda*.

"It was as parallel-sided as I have drawn it, with very well-defined edges, *i.e.* as well defined as any comets ever are.

"The brightness of it was about that of a *fine* comet.

"The condensation of light towards the base was *quite* pronounced, and had a definite parallelism with its sides. *It did not correspond to* the condensation in a comet's tail before reaching the nucleus.

"We could not guess what was below the tree-tops, but it looked to me as if the head of the comet, if there, could not be far off; all that was certain was that the condensation of light was not nuclear, but axial. The tint of this part was rather ruddy, the rest ordinary pale yellow.

"The whole thing was a striking, sharply defined object, and therefore quite alien, to my knowledge, to the idea of the zodiacal light; and yet its position and my previous conclusion about the zodiacal light oblige me to suppose that I do not really know what the zodiacal light *can* look like. On the other hand, I cannot conceive how this second object could, an hour or so earlier (when it was concealed behind a bank of clouds), have been seen to extend over the zodiacal light area nearly up to the *Pleiades*. The axis of the 'comet,' by the way (being definite), passed *clear to the left* of the *Pleiades*.

"*Littlemore, near Oxford:*
"1896 *March* 4."

Later Sir W. J. Herschel sent me the following cutting from the *Evening Standard* referring to the same phenomenon :-

"*Meteoric Light.*

"To the Editor of the *Evening Standard.*

"SIR,—On Wednesday evening, a little after eight o'clock, there appeared in the western sky, a little above the horizon, a broad light, something like the tail of a comet, spreading up to about a third of a demi-semicircle of the heavens. The width of the light kept nearly the same till it tapered off a little, high up in the sky. There were on the sides smaller rays of light, emanating as it were from the central luminous body. It lasted for more than an hour after I first saw it; whether it was visible before eight o'clock I cannot say.—I. G. MONCKTON.

"*Coven Vicarage, Wolverhampton:*
"1896 *March* 6."

In reply to an inquiry as to any disturbance of the magnetic registers on the evening in question, the Astronomer Royal kindly sent me the following note:—

"*Magnetic Disturbance of* 1896 *March* 4–5.

"The date is omitted in Professor Turner's letter, but the reference would appear to be to the disturbance shown on the night of March 4–5 (active about midnight).

"There were minor movements on the preceding night (March 3), and small active movements preceding the major effects (above mentioned) from March $4^d\ 7^h$.

"[H.F. and Dec. Phot. Records for 1896 (March 3^d–4^d, and March 4^d–5^d accompany this note.]"

Mr. H. F. Newall has also kindly sent me the following notes from Cambridge, where a ray was seen in the west, not quite at the same time, and was regarded as auroral. Mr. Goatcher noted on 1896 March 4 at $8^h\ 21^m$ a bright ray extended from top of trees to *α Trianguli*, of yellow colour, about parallel to *α* and *β Andromedæ*, and widening as altitude increased. It grew fainter, and was evidently shifting southwards.

$8^h\ 31^m$, ray extremely faint; reaches only to *γ Arietis*; is still parallel to original direction.

$8^h\ 45^m$, ray invisible. No quivering of light was observed in the ray.

$10^h\ 30^m$–13^h, greenish glow in magnetic N.; yellow and green auroral lines visible in spectroscope.

Note on the Zodiacal Light of 1896 *March* 4. By W. H. Robinson, Assistant at the Radcliffe Observatory.

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The zodiacal light was seen at the Radcliffe Observatory between 7 and 8 P.M. on Wednesday, March 4.

It was very distinct and bright, extending in the usual lenticular form nearly to the *Pleiades.*

The sky at the time was very clear, but clouds prevailed from 8 until 9 o'clock, when observations were resumed with the heliometer. The N.W. sky was examined for a few seconds soon after 10 o'clock, but only a low, faint haze was then visible.

The zodiacal light is frequently seen here about the time of the vernal equinox. This year, however, it was visible as early as January 9 at 7 P.M.

Radcliffe Observatory, Oxford:
1896 *March* 12.

Letter from H. C. Russell. Supposed Observation of a Comet.

The Hon. Secretary
Royal Astronomical Society.

DEAR SIR,

If you have no better information about the object described, perhaps the facts stated by Mr. Parker may be woith publication. A great number of persons saw this object both in South Australia and New South Wales. Here it was cloudy every night, and our diligent search was not rewarded.

Notwithstanding the measure of the comet in feet and inches, Mr. Parker's account is much better than any others which have appeared in the local press.

In December our sky is so bright near sunset that you could not see a first-magnitude star in the position the comet is said to have occupied with reference to the Sun.

Yours truly,
H. C. RUSSELL.

It was not seen, I understand, either at Adelaide or Melbourne.

Sydney Observatory:
1896 *January* 18.

Copy of a Letter from the Postmaster at the little village of Hungerford, Long. 144° 30′ *East, Lat.* 29° 0′ *West.*

SIR,

I have the honour to inform you, in reply to your memo. of even date, that the comet was first seen by several persons, including myself, on the 21st inst., shortly after sunset. It was visible fully an hour. Position was W.S.W., not due west as originally notified. Sky divided by six, *i.e.* 15°, would give approximate height when first seen, but it descended rapidly. The tail was apparently 5 feet long by about 18 inches to 6 inches wide. Nucleus small, fairly bright. It was quite distinct. Several people on Caiwarro Station, forty miles distant N.E., saw it on 22nd inst.

On 22nd it was very similar to 21st, but much brighter: 23rd and 24th appeared with greater brilliancy almost immediately after sunset, almost level with the horizon, but soon disappeared.

Sky been too cloudy since to see it.

I have the honour to be, Sir,
Your obed. Servant,
A. E. PARKER,
Postmaster.

The Government Astronomer,
Sydney.

Hungerford: 1895 *December* 27.

Note on the Sensibly Cylindrical Forms of the Pivots of the Transit Circle of the Radcliffe Observatory. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The comparisons which have been made between the right ascensions observed with the Oxford, Cape, and Greenwich transit circles have shown the existence of small but sensible differences depending on the N.P.D. of the object observed. See *Monthly Notices*, vol. lv. p. 292.

The Oxford instrument was not originally provided with any suitable means of examining the form of the pivots ; and so long as the form of the pivots of the transit circle of the Radcliffe Observatory had not been examined, it was possible to suppose that these discordances might be due to the deviations of the pivots from cylindrical forms. I have therefore for some time had under consideration the best means of testing the form of the pivots.

In the *Comptes Rendus de l'Académie des Sciences*, 1893 November 13, Mons. Maurice Hamy has called attention to the suitability of Mons. Fizeau's method of measuring the dilatation of crystals for the determination of the errors of the pivots of transit circles. See *Comptes Rendus*, 1862 June 23, and 1864 May 23.

This method appeared to me to offer great facilities for an examination of our pivots ; and I have therefore obtained from Mr. Simms the necessary apparatus.

The general principle is simply that a shift of fringes of interference necessarily results from changes in the thickness of the layer of air between the plane surface of the object-glass of a *fixed* microscope and a plane reflector adjusted to sensible parallelism. The plane reflector is connected by levers with the pivots in such a way that its position is very sensibly affected by any slight deviations in the form of the pivots as the transit circle is turned around its axis ; whilst its position remains unaltered and the fringes unaffected if no such deviations from the cylindrical form of the pivots exist.

The examination which I have made, with this instrument, of the form of the pivots shows that, although there are *traces* of slight variations from cylindrical forms, the errors are so small that they are practically insensible ; the errors, in fact, are only such as would lead to differences of level error in different positions of the instrument of about $\frac{2}{100}$ of a second of arc.

It is certain, therefore, that the differences in right ascensions, to which attention has been called, are not due to pivot errors in the Radcliffe transit circle.

On the Proper Motions of certain Fundamental Stars.
By W. G. Thackeray.

As Dr. Chandler and Professor Newcomb have been lately discussing the question of Auwers' proper motions, *A.J.*, Nos. 364, 365, it appears a favourable opportunity to give the result of the discussion of some values of proper motions derived from the Greenwich observations, 1836–1893. The particular object in view at the time was to find a number of stars which had been consistently and continually observed over an extended period; but it was soon discovered that there were but few stars which could be so classed. Some were well observed at the beginning of the period, but not at the end, and *vice versa*; while others had awkward gaps at intermediate intervals. At present only thirty-six stars have been dealt with, and some of these can by no means be considered as fulfilling the wished-for conditions.

The right ascensions here dealt with were observed with the transit instrument from 1836 to 1850, and with the transit circle from 1851 to 1893. They have all been reduced to the epoch of 1890, and to the equinox of the 1880 Catalogue according to the following table, with Auwers-Bradley proper motions and Peters' constants of precession.

Table I.

Corrections to reduce Greenwich Observations 1836–76 to the Equinox of the 1880 Catalogue.

Year.	Name of Catalogue.	Corrections to Catalogue R.A.	Corrections to Annual Mean R.A.	Year.	Name of Catalogue.	Corrections to Catalogue R.A.	Corrections to Annual Mean R.A.
		s	s			s	s
1836			−·026	1848			+·062
1837			−·021	1849			·000
1838	1840 Cat.	+·055	−·031	1850	1850 Cat.	−·010	·000
1839			−·030	1851			·000
1840			−·031	1852			·000
1841			−·035	1853			·000
1842			−·011	1854			−·003
1843			+·078	1855			−·003
1844	1845 Cat.	+·010	+·066	1856			−·013
1845			+·087	1857	1860 Cat.	−·003	−·013
1846			+·048	1858			−·013
1847			+·060	1859			−·013
				1860			−·013
1861–67	1864 Cat.	+·007	−·003	1868–76	1872 Cat.	·000	·000

The residual proper motion was therefore a direct correction to Auwers' values, and its amount was obtained in most cases by plotting every year's result and drawing the best straight line through the series. In those cases, therefore, where the correction to the proper motion is described as $^{s}\!\cdot0000$ it is to be inferred that the observations were practically satisfied by the value found by Auwers. Out of the thirty-six stars twenty-three showed sensible corrections, which are mostly plus for the first twelve hours of R.A., and between declination $-16°$ and $+16°$, and minus for the last twelve hours of R.A., and between declination $+16°$ and $+52°$.

The north polar distances were observed with the Jones and Troughton circles 1836–39, with the Troughton circle 1840–47, with the Troughton and Jones Cape circle for the year 1848, with the Troughton circle 1849–50, and with the transit circle 1851–94.

The observations of 1836–47 have been reduced to colatitude $21''\cdot83$, those of 1849–50 to colatitude $21''\cdot94$, and those of 1851–93 to colatitude $21''\cdot90$. The observations 1851–93 have been further corrected where necessary to reduce them to Bessel's refractions, flexure $=\cdot000$ and formula for $R-D = a+b \sin Z$, which latter correction practically implies that the value of the flexure is determined from positions of the instrument in constant use for observations in preference to the value obtained from a position which is never in use for observation (*i.e.* the horizontal position on the collimators), though theoretically the two values ought to be the same. In addition, corrections have also been applied for the wear in the microscope micrometers 1868–78. No corrections have been applied for Dr. Chandler's latitude variation.

The observations have all been reduced to 1890 with Auwers-Bradley corrections for proper motion, and Peters' constant of precession, and the annual results plotted down, and in most cases the best straight line drawn through the series represented the resulting proper motion, which is the direct correction to Auwers' value, and $''\cdot000$ is therefore to be considered as the sign that the Greenwich observations show no sensible corrections to the values found by Professor Auwers. Out of thirty-six stars twenty-three showed sensible corrections.

In *A.J.*, Nos. 313, 315, and 320, Dr. Chandler has rediscussed the observations made at Greenwich with the mural circles by Troughton and by Jones for the years 1825–48, and in *A.J.*, No. 361, he has found for thirty-four of these stars new values of proper motions from the following combinations :—

(1) Pond's observations 1825–35, and those of the Greenwich Five-year Catalogue 1890.

(2) Airy's observations 1836–48, and the Madison observations 1887–92.

(3) The Pulkova Catalogue of 1845 and the Pulkova Catalogue 1885.

These results, combined with weights thirteen, eight, and nine respectively, are exhibited in *A.J.*, No. 364, as corrections to the proper motions of Auwers and Boss, and have been incorporated in the following table for comparison with the values deduced from the Greenwich observations 1836–93.

The following, Table II., contains a list of stars whose proper motions have been redetermined either by Chandler or at Greenwich: columns three and four give the approximate R.A. and Decl. for 1890; column five gives the corrections applied by Auwers to Bradley's observed declinations reduced to 1755 from the table given on p. 252, vol. ii. of the *Neue Reduction der Bradleyschen Beobachtungen.* These corrections for the circumpolar stars have been combined with weights according to the number of observation above and below pole. Column six gives the corrections to Auwers-Bradley's proper motions in R.A. deduced from the Greenwich observations 1836 93. Columns seven and ten give similar corrections to Auwers-Bradley and Boss' proper motions in declination. Columns eight and nine give Chandler's and Boss' corrections referred to above.

All these quantities are arranged in order of right ascension.

Table III. gives the same quantities, arranged in order of declination.

Gr refers to the proper motions deduced from Greenwich observations 1836–93.

A refers to the proper motions deduced by Auwers from Bradley's observations.

B refers to the proper motions deduced by Boss.

C refers to the proper motions deduced by Chandler, *A.J.*, No. 361, p. 3.

TABLE II.

Order of Right Ascension.

Differences of Proper Motion in (1) *Right Ascension and Declination between Auwers-Bradley and Greenwich observations* 1836–93; *in* (2) *Declination between Auwers-Bradley and Chandler.* "*A.J.*," *No.* 364, *p.* 29; *in* (3) *Declination between Auwers-Bradley and Boss' Standard Catalogue; and in* (4) *Declination between Boss' and Greenwich observations* 1836–93.

Ref. No.	Star's Name.	App. R.A. 1890.	App. Dec. 1890.	Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Diff. of P.M. Declination. Gr−A.	C−A.	B−A.	Gr−B.
		h m	° ′	″	s	″	″	″	″
1	α Andromedæ	0 3	28 3	+0·56	·0000	·000	−·009	−·011	+·011
2	γ Pegasi	0 8	14 6	+0·41	·0000	·000	−·006	−·006	+·006
3	α Cassiopeiæ	0 34	55 9	−0·42	...	...	−·002	−·003	...
3a	μ Andromedæ	0 50	37 9	−0·55	−·0038	−·019	...	−·042	+·023
4	β Andromedæ	1 4	35 0	−0·05	−·0005	−·027	...	−·038	+·011
5	α Arietis	2 1	22 9	−0·18	−·0004	−·016	−·018	−·017	+·001
6	α Ceti	2 57	3 7	+0·62	+·0010	·000	...	−·013	+·013
7	Aldebaran	4 30	16 2	+0·87	−·0008	·000	−·011	−·008	+·008
8	Rigel	5 9	−8 3	+0·31	·0000	·000	...	−·011	+·011

Ref. No.	Star's Name.	App. R.A. 1890.	App. Dec. 1891.	Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Diff. of P.M. Declination. Gr−A.	O−A.	B−A.	Gr.−B.
		h m	° ′	″	s	″	″	″	″
9	Capella	5 9	45 9	−0·63	−·0040	·000	−·006	−·010	+·010
10	β Tauri	5 19	28 5	+0·30	−·0004	+·015	+·002	−·001	+·016
11	α Orionis	5 49	7 4	−0·06	·0000	−·010	−·020	−·017	+·007
12	Sirius	6 39	−16 5	+0·18	−·0010	−·030	...	...	...
13	Castor	7 28	32 2	+0·16	−·0005	−·012	+·006	·000	−·012
14	Procyon	7 34	5 7	+0·24	−·0005	·000	...	...	...
15	Pollux	7 39	28 4	+0·31	−·0006	·000	−·010	−·006	+·006
16	Regulus	10 3	12 5	+0·30	·0000	−·018	−·017	−·019	+·001
17	α Ursæ Majoris	10 56	62 3	+0·09	...	...	·000	−·004	...
18	δ Leonis	11 8	21 1	−0·12	...	...	−·024	−·027	...
19	β Leonis	11 43	15 2	+0·86	·0000	−·020	...	−·021	+·001
20	δ Ursæ Majoris	12 10	57 6	−0·10	...	...	+·012	+·005	...
21	Spica	13 19	−10 6	0·00	+·0006	−·010	...	−·020	+·010
22	η Boötis	13 49	19 0	+0·10	−·0004	−·008	...	−·017	+·009
23	α Draconis	14 1	64 9	0·00	...	...	+·002	−·010	...
24	Arcturus	14 11	19 7	+0·06	+·0006	−·017	−·020	−·023	+·006
25	ε² Boötis	14 40	27 6	+0·41	·0000	+·016	...	−·009	+·025
26	β Ursæ Minoris *	14 51	74 6	−0·50	...	...	·000	−·009	...
27	α Coronæ	15 30	27 1	+0·61	·0000	·000	−·006	−·006	+·000
28	α Serpentis	15 39	6 8	−0·04	+·0003	−·008	−·015	−·022	+·014
29	ζ Herculis	16 37	31 8	+0·11	−·0014	−·025	...	−·009	−·016
30	α Herculis	17 10	14 5	+0·60	+·0006	·000	−·003	−·004	+·004
31	α Ophiuchi	17 30	12 6	+0·24	+·0004	−·014	−·017	−·020	+·006
32	γ Draconis	17 54	51 5	+0·20	+·0004	·000	...	−·002	+·002
33	α Lyræ	18 33	38 7	−0·18	·0000	−·020	−·020	−·023	+·003
34	β Lyræ	18 46	33 2	+0·15	+·0005	−·024	−·024	−·034	+·010
35	ζ Aquilæ	19 0	13 7	+0·35	...	...	−·016	−·014	...
36	δ Draconis	19 13	67 5	+0·26	...	...	+·003	+·006	...
37	γ Aquilæ	19 41	10 3	−0·20	+·0008	−·020	−·019	−·016	−·004
38	α Aquilæ	19 45	8 6	−0·28	·0000	−·020	−·014	−·014	−·006
39	β Aquilæ	19 50	6 1	+0·24	+·0014	−·008	−·016	−·019	+·011
40	α² Capricorni	20 12	−12 9	+0·12	+·0020	−·016	...	−·017	+·001
41	α Cygni	20 38	44 9	+0·60	·0000	−·015	−·010	−·011	−·004
42	α Cephei	21 16	62 1	0·00	...	...	+·026	+·017	..
43	β Cephei	21 27	70 1	+0·25	...	...	+·014	+·007	...
44	α Aquarii	22 0	−0 9	+0·98	+·0004	·000	...	−·016	+·016
45	α Pegasi	22 59	14 6	+0·41	·0000	−·016	−·018	−·020	+·004

* One observation only in Bradley.

TABLE III.

Order of Declination.

Difference of Proper Motion from Table I.

Ref. No.	Star's Name.	Approx. Dec. 1890.		Approx. R.A. 1890.		Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Difference of P.M. Declination. Gr−A.	C−A.	B−A.	Gr−B.
		°	′	h	m	″		″	″	″	″
12	Sirius	−16	5	6	39	+0·18	−·0010	−·030	...	...	...
48	α^2 Capricorni	−12	9	20	12	+0·12	+·0020	−·016	...	−·017	+·001
21	Spica	−10	6	13	19	0·00	+·0006	−·010	...	−·020	+·010
8	Rigel	−8	3	5	9	+0·31	·0000	·000	...	−·011	+·011
44	α Aquarii	−0	9	22	0	+0·98	+·0004	·000	...	−·016	+·016
6	α Ceti	+3	7	2	57	+0·62	+·0010	·000	...	−·013	+·013
14	Procyon	5	7	7	34	+0·24	−·0005	·000	...	...	...
39	β Aquilæ	6	1	19	50	+0·24	+·0014	−·008	−·016	−·019	+·011
28	α Serpentis	6	8	15	39	−0·04	+·0003	−·008	−·015	−·022	+·014
11	α Orionis	7	4	5	49	−0·06	·0000	−·010	−·020	−·017	+·007
38	α Aquilæ	8	6	19	45	−0·28	·0000	−·020	−·014	−·014	−·006
37	γ Aquilæ	10	3	19	41	−0·20	+·0008	−·020	−·019	−·016	−·004
16	Regulus	12	5	10	3	+0·30	·0000	−·018	−·017	−·019	+·001
31	α Ophiuchi	12	6	17	30	+0·24	+·0004	−·014	−·017	−·020	+·006
35	ζ Aquilæ	13	7	19	0	+0·35	...	...	−·016	−·014	...
30	α Herculis	14	5	17	10	+0·60	+·0006	·000	−·003	−·004	+·004
2	γ Pegasi	14	6	0	8	+0·41	·0000	·000	−·006	−·006	+·006
45	α Pegasi	14	6	22	59	+0·41	·0000	−·016	−·018	−·020	+·004
19	β Leonis	15	2	11	43	+0·86	·0000	−·020	...	−·021	+·001
7	Aldebaran	16	2	4	30	+0·87	−·0008	·000	−·011	−·008	+·008
22	η Boötis	19	0	13	49	+0·10	−·0004	−·008	...	−·017	+·009
24	Arcturus	19	7	14	11	+0·06	+·0006	−·017	−·020	−·023	+·006
18	δ Leonis	21	1	11	8	−0·12	...	...	−·024	−·027	...
5	α Arietis	22	9	2	1	−0·18	−·0004	−·016	−·018	−·017	+·001
27	α Coronæ	27	1	15	30	+0·61	·0000	·000	−·006	−·006	+·006
25	ϵ^2 Boötis	27	6	14	40	+0·41	·0000	+·016	...	−·009	+·025
1	α Andromedæ	28	3	0	3	+0·56	·0000	·000	−·009	−·011	+·011
15	Pollux	28	4	7	39	+0·31	−·0006	·000	−·010	−·006	+·006
10	β Tauri	28	5	5	19	+0·30	−·0004	+·015	+·002	−·001	+·016
29	ζ Herculis	31	8	16	37	+0·11	−·0014	−·025	...	−·009	−·016
13	Castor	32	2	7	28	+0·16	−·0005	−·012	+·006	·000	−·012
34	β Lyræ	33	2	18	46	+0·15	+·0005	−·024	−·024	−·034	+·010
4	β Andromedæ	35	0	1	4	−0·05	−·0005	−·027	...	−·038	+·011
3a	μ Andromedæ	37	9	0	50	−0·55	−·0038	−·019	...	−·042	+·023

Ref. No.	Star's Name.	Approx. Dec. 1890.		Approx. R.A. 1890.		Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Difference of P.M. Declination.			
								Gr−A.	C−A.	B−A.	Gr−B.
		°	′	h	m	″		″	″	″	″
33	α Lyræ	38	7	18	33	−0·18	·0000	−·020	−·020	−·023	+·003
41	α Cygni	44	9	20	38	+0·60	·0000	−·015	−·010	−·011	−·004
9	Capella	45	9	5	9	−0·63	−·0040	·000	−·006	−·010	+·010
32	γ Draconis	51	5	17	54	+0·20	+·0004	·000	...	−·002	+·002
3	α Cassiopeiæ	55	9	0	34	−0·42	...	...	−·002	−·003	...
20	δ Ursæ Majoris	57	6	12	10	−0·10	...	...	+·012	+·005	...
42	α Cephei	62	1	21	16	0·00	...	...	+·026	+·017	...
17	α Ursæ Majoris	62	3	10	56	+0·09	...	...	·000	−·004	...
23	α Draconis	64	9	14	1	0·00	...	...	+·002	−·010	...
36	δ Draconis	67	5	19	13	+0·26	...	...	+·003	+·006	...
43	β Cephei	70	1	21	27	+0·25	...	...	+·014	+·007	...
26	β Ursæ Minoris*	74	6	14	51	−0·50	...	...	·000	−·009	...

* One observation only in Bradley.

The following general conclusions, making due allowance for the number of stars under discussion, may be drawn from these tables :—(1) That the proper motions deduced by Chandler and Boss agree very closely. (2) That there are systematic discordances either in the proper motions deduced by Auwers or in those deduced by Chandler and Boss. (3) That the Greenwich proper motions lie between those of Auwers and those of Chandler and Boss, and do not support the latter in attributing the systematic discordances as all due to Auwers. (4) That the corrections applied by Auwers to Bradley's observations (as far, at any rate, as the declinations covered by the clock-star system) are not in the main otherwise than beneficial, though they aggravate the large discordances shown to exist in the zones $+6°·8$ to $0°·3$ and $+35°$ to $+38°$ (see Professor Newcomb's paper on Boss' System of Declinations, *A.J.*, No. 365, p. 34). (6) That in any case the mean effect of these corrections is very small, $+0''·18$.

Now, if we take the mean of columns 5, 7, 9, and 10 of Table II. for those stars only whose proper motions have been re-determined at Greenwich, not including *Sirius* or *Procyon*, we shall get

Gr−A.	B−A.	Gr−B.	Effect of Auwers' Corr. on P.M.
$-''·0088$	$-0''·0153$	$+''·0068$	$-''·0016$

Thus it would appear that the mean effect of Auwers' correction is to reduce the quantities Gr − A and B − A by $''·0016$.

Now from Chandler's papers, *A.J.*, 364, p. 29, we find that the mean difference between Chandler's and Boss' systems of proper motions is $C-B=+''·0021$, which would make $Gr-C=+''·0047$,

and from his paper, *A.J.*, No. 361, we learn that in the reduction of the Greenwich mural circle observations he has adopted $38''\cdot42$ for the mean value of the latitude. From independent sources we know the mural circles were $0''\cdot07$ north of the present transit circle, which makes this adopted value of the mean latitude referred to the present transit circle $38''\cdot35$, whereas the value adopted at Greenwich in the reductions of the Five-year Catalogue, 1890, is $38''\cdot10$. For the purpose of obtaining values of the proper motion one or other of these sets of observations should be altered. Correcting Chandler's value, and taking fifty-five years as about the period over which the observations extend, and allowing for Chandler's weights, we get a correction of $+0''\cdot0031$ to Chandler's proper motions; a quantity which satisfactorily accords with the value $+\cdot0047$ given for Gr − C.

If we take the mean values of the three different determinations of all the proper motions given by Chandler, *A.J.*, No. 361, p. 3, we get

Gr. (5 year 1890) and Pond.	Madison and Airy.	Pulkova 1845 and 1885.
$-0''\cdot111$	$-0''\cdot112$	$-0''\cdot105$

from which it appears that the correction to the mean of the first two systems to reduce to that of Pulkova is $+''\cdot0065$; a value which also confirms the difference $+''\cdot0047$ shown to exist between Chandler and Greenwich, as also the validity of the assumption of an alteration of Chandler's Pond-Airy reductions.

Finally, in *A.J.*, No. 365, Professor Newcomb has pointed out that from the planetary theories (*Astronomical Constants*, p. 89) the general correction to Boss' system $= +0''\cdot09 + 0''\cdot42$ T, where T is the time from 1850 in terms of the century as unit; also that the value of the secular term may be in error some $\pm 0''\cdot30$. This, again, confirms the mean correction of $+0''\cdot0068$ to Boss' proper motions given by the Greenwich system 1836–93, and testifies to the general correctness of the latter system.

Errata to Paper on Meridian Observations of Sirius and Procyon at the Royal Observatory, Greenwich, 1836–94. By W. G. Thackeray.

Corrections to reduce Greenwich Observations 1836–76 *to the Equinox of the Ten-year Catalogue,* 1880 (*Errata to Columns* 8 *and* 9 *of Table II.,* "*Monthly Notices,*" lvi. 1, pp. 18, 19).

Year.	Name of Catalogue.	Corr. to Catalogue R.A. (8)	Corrections to Annual Mean R.A. (9)	Year.	Name of Catalogue.	Corr. to Catalogue R.A. (8)	Corrections to Annual Mean R.A. (9)
		s	s			s	s
1836			−·026	1848			+·062
1837			−·021	1849			·000
1838	1840 Cat.	+·055	−·031	1850	1850 Cat.	−·010	·000
1839			−·030	1851			·000
1840			−·031	1852			·000
1841			−·035	1853			·000
1842			−·011	1854			−·003
1843			+·078	1855			−·003
1844	1845 Cat.	+·010	+·066	1856			−·013
1845			+·087	1857	1860 Cat.	−·003	−·013
1846			+·048	1858			−·013
1847			+·060	1859			−·013
				1860			−·013
				1861–67	1864 Cat.	+·007	−·003
				1868–76	1872 Cat.	·000	·000

In consequence of these corrections to Table I. both *Sirius* and *Procyon* now appear to require small corrections to the adopted proper motions (those of Dr. Auwers) in right ascension, that of *Sirius*, $-0^{s}\cdot0010$, making its proper motion $-0^{s}\cdot0382$, that of *Procyon*, $-0^{s}\cdot0005$, making its proper motion $-0^{s}\cdot0479$. The following table embodying these corrections should therefore be substituted for Tables III. and IV. in the former paper, and the adopted secs. of R.A. 1890·0 should be further corrected for the new proper motions :—

Errata in Right Ascensions of Sirius and Procyon as given in Tables III. and IV. "Monthly Notices," lvi. 1, pp. 22–25.

Year.	Sirius. Mean Right Ascension.	Sirius. Adopted Secs. of R.A. 1890·0.	Procyon. Mean Right Ascension.	Procyon. Adopted Secs. of R.A. 1890·0.
	s	s	s	s
1836	55·370	18·090	42·800	32·560
1837	58·060	·140	45·980	·600
1838	0·690	·120	49·090	·550
1839	3·390	·180	52·250	·570
1840	6·040	·160	55·380	·530
1841	8·660	·130	58·530	·530
1842	11·390	·200	1·750	·610
1843	14·000	·250	4·830	·630
1844	16·580	·170	8·000	·640
1845	19·210	·180	11·160	·680
1846	21·840	·120	14·280	·610
1847	24·430	·080	17·440	·640
1854	42·790	17·980	39·490	·690
1855	45·480	18·020	42·640	·700
1856	48·120	·000	45·790	·700
1857	50·700	17·940	48·910	·670
1858	53·280	·880	52·020	·640
1859	55·980	·940	55·160	·630
1860	58·600	·910	58·370	·650

The effect of these corrections is to make the agreement between Dr. Auwers' orbital corrections and the observations closer than before.

Variation of T Centauri (Ch. 4896). By A. W. Roberts.

In the *Monthly Notices* for November 1895 Colonel Markwick contributes a paper upon the variation of *T Centauri*.

This star was frequently observed at Lovedale during 1895, and as the elements of variation determined from these observations do not quite agree with those obtained by Colonel Markwick it is of present interest to deal with the Lovedale observations.

In determining the magnitude of *T Centauri* the following comparison stars were employed:—

C. Z. C.	R.A. (1875).	Dec.	Mag.
	h m s	° ′	
2115	13 35 10	33 20·9	6·60
1910	31 43	32 28·5	6·70
2033	33 51	33 49·4	7·00
2003	33 21	33 43·4	7·30
1630	27 8	33 44·7	7·60
1711	28 22	33 22·6	7·75
1624	27 4	33 25·6	7·80
2386	39 17	33 8·8	7·93
2152	35 42	32 2·2	8·13
1746	28 58	33 44·0	8·50
1838	30 31	33 40·0	8·60
2299	38 6	32 38·7	8·60
2082	34 36	33 7·9	8·85
2362	38 52	32 50·4	8·90
2212	36 37	32 32·1	9·00
2240	37 7	32 34·1	9·00
2039	13 34 0	33 1·3	9·10

For magnitudes brighter than 6·5 the comparison stars used in observing l, R and S *Carinæ* were employed.

The magnitudes of the foregoing stars are determined from two reference points, viz. 6·8 and 9·3. The former magnitude is that of a star just visible to the naked eye; the latter is the lowest magnitude visible in a 1-inch glass.

The detailed observations are as follows :—

1895.	m	1895	m	1895	m
Mar. 21·4	6·20	April 27·3	8·85	June 22·5	6·00
22·4	6·20	29·3	8·90	25·5	6·40
27·4	6·30	May 14·3	7·15	July 16·4	8·15
29·5	6·40	15·4	7·10	25·3	9·05
April 3·3	6·80	18·3	7·00	Aug. 9·3	8·10
12·3	7·65	20·3	6·65	12·4	8·00
15·3	8·00	27·5	6·60	14·4	7·53
21·3	8·20	31·6	6·20	15·3	7·40
22·4	8·45	June 14·5	6·00	16·3	7·30
24·4	8·75	15·5	6·20	21·3	7·00
26·3	8·95	18·4	6·20	24·3	7·00
		20·4	5·90	27·4	6·75

Each observation is the mean of two others: one taken with the direct vision eye-piece, the other with the reversing eye-piece.

In this way the error arising from the position of the variable with relation to the surrounding comparison stars was eliminated.

Charting down the several observations we obtain the light curve given in the diagram, an examination of which yields the following elements :—

Period	91·2 days.
Min. to Max.	42 days.
Max. to Min.	49 days.
Epoch of Max.	1895 June 9.
Max. limit	5·85 Mag.
Min. limit	9·15 Mag.

The main points of difference between these elements and those determined by Colonel Markwick are the period and the magnitude at minimum phase.

Both Colonel Markwick's observations and my own indicate a minimum on or about April 25.

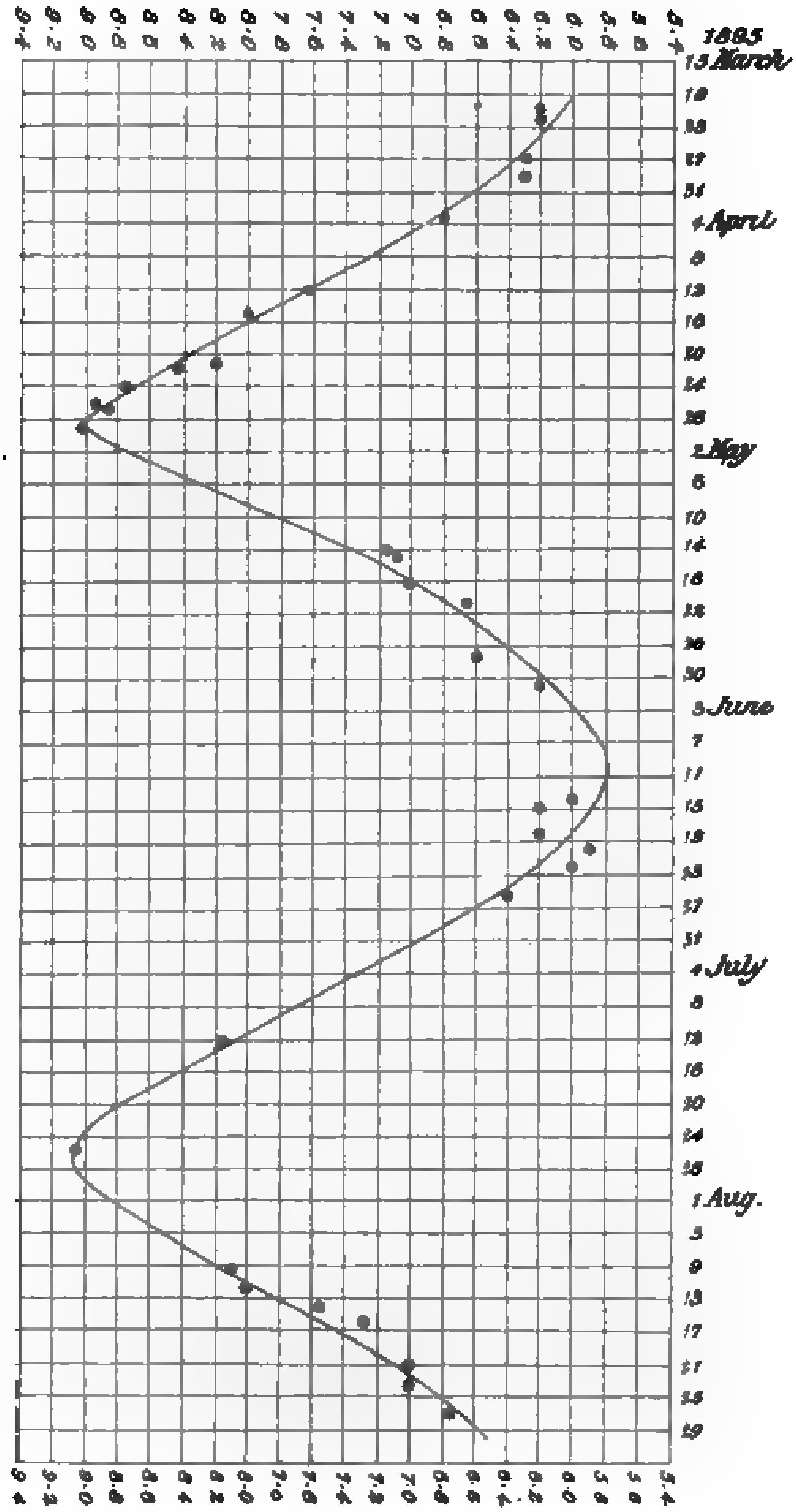
On April 25 and 26 Colonel Markwick estimated *T Centauri* to be of the 10th mag. On April 24 and 26 I found in the 1-inch glass, the limit of vision of which is 9·3 mag., that it was 8·75 and 8·95 respectively.

As regards the period, I think it will be found that a period of 91 days satisfies the data collected by Colonel Markwick in his interesting paper. Especially is this the case with the interval of 638 days between the minimum observed at Arequipa on 1893 July 27 and that observed by Colonel Markwick on 1895 April 26. Taking *seven* periods (instead of nine) to have elapsed between the two dates we obtain a mean period of 91·1 days.

The magnitudes given in meridian catalogues are very insecure data to base a determination of light period upon. As often as not the observer copies down the magnitude from his observing list, and even if an estimate of magnitude were made as the star crossed the field it would be but at best a rude guess. It is needless, therefore, to enter into an inquiry as to the agreement between the elements just given and the magnitudes in meridian catalogues.

But of more importance than this comparison between ephemerides computed from elements of variation and magnitudes in star catalogues is the method of determining the principal elements of variation—viz. the period. The usual method employed is to compare isolated measures made at or near one maximum with those made at another maximum.

It is evident that errors in estimating the magnitudes made use of in the computation will influence the result to no small extent. Further, the maximum phase of most long-period



Light Curve of *T Centauri.*

variables is not distinctly marked, and thus the determination of a point of reference depends a good deal upon the observer.

By far the better mode of determination is to compare light curves by superposition. By this method the period depends, not upon two or three isolated observations, but upon every observation made.

It was by this method, by comparing the curve (fig. 1) during March, April, May with that during June, July, August, that the period of *T Centauri* (91·2 days) given in this paper was arrived at.

Lovedale:
January 1896.

Observations of the Variable Star R Carinæ from 1890 *December to* 1895 *August.* By John Tebbutt.

In volumes xliv., xlvi., and li. of the Society's *Monthly Notices* comparisons of *R Carinæ* were published by me extending from 1880 May to 1890 June. Since the latter year I have been unable to keep up continuous observations of this interesting variable; still, scattered as the comparisons are, they may in combination with others—notably those made by Mr. A. W. Roberts, of South Africa—serve to throw light on its variations since 1890. I therefore enclose my results from 1890 December to August of the current year. While the variable was visible to the naked eye comparison stars were taken from the *Uranometria Argentina.* When the variable was telescopic the list of comparison stars employed was that given in *Monthly Notices*, vol. xliv. p. 17. It will be seen that the comparisons in 1891, 1892, 1894, and 1895 are sufficiently frequent to enable us to determine pretty accurately the maxima for those years. It also appears from a comparison of the observations made at Cordoba in 1871 with those made at Windsor in 1895 that the mean period of the star's variations from maximum to maximum is about 311 days, or about a day less than that which I deduced from observations down to 1886. I may here remark that there is a misprint on page 16 of the forty-fourth volume of the *Notices*, which I believe has not yet been corrected. The concluded magnitude opposite to 1882 December 12 should be 8·6 instead of 9·8.

Concluded Magnitudes of R Carinæ.

Date.	Mag.	Date.	Mag.	Date.	Mag.
1890 Dec. 30	8·0	1892 Jan. 31	5·7	1895 Apr. 4	6·9
1891 Jan. 12	7·0	Feb. 7	5·8	14	5·7
Feb. 7	5·6	19	6·3	21	5·5
11	5·5	Mar. 1	6·4	25	5·5
17	5·6	10	6·4	30	5·4
21	5·5	25	6·6	May 2	5·4
27	5·5	May 31	9·1	6	5·3
Mar. 3	5·6	Dec. 21	6·2	11	5·2
8	5·5	1893 Apr. 10	9·2	13	5·1
16	5·6	1894 Apr. 2	8·9	16	5·2
21	5·7	June 26	6·1	1	5·3
30	5·8	30	6·1	21	5·4
Apr. 6	5·9	July 7	5·7	25	5·5
10	5·9	15	5·8	26	5·6
17	6·0	20	5·9	29	5·7
21	6·3	28	6·0	June 3	5·8
30	6·4	Aug. 4	6·3	8	5·9
May 5	6·5	18	6·9	11	6·1
17	6·7	24	7·3	16	6·3
18	6·9	1895 Feb. 13	8·6	19	6·3
June 3	8·0	18	8·5	24	6·5
Dec. 30	5·3	27	8·3	27	6·5
1892 Jan. 2	5·3	Mar. 8	8·2	July 9	6·9
15	5·5	19	7·7	25	8·0
21	5·6	25	7·6	Aug. 21	8·5
24	5·6				

The Peninsula, Windsor, N.S. Wales:
1895 *December* 8.

Results of Double-star Measures with the 8-inch Equatorial at Windsor, New South Wales, in 1895.
By John Tebbutt.

Ref. No.	Star.	Observed Magnitudes.	Approx. Place of Star 1895·0. R. A.	Approx. Place of Star 1895·0. Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.	Hour-angles.	Weight, 1 to 5
			h m	° ′		°		″				h m	h m	
1	*p* Eridani	6, 6	1 36	56 44	·830	225·5	10	7·64	8	300	R	3 4 E	2 31 E	3
2	„	...	„	„	·871	223·5	10	...	...	300	P	0 53 E	0 35 E	4
3	„	...	„	„	·931	225·1	10	...	...	300	R	0 37 E	0 17 E	3
4	„	...	„	„	·936	222·6	10	7·41	6	300	P	1 13 E	0 42 E	2
5	„	6, 6	„	„	·977	225·1	10	7·61	6	300	R	3 25 W	3 53 W	4
6	„	6, 6	„	„	·983	224·4	10	7·41	6	300	R	1 12 W	1 37 W	3
7	„	6, 6	„	„	·988	224·8	10	7·38	7	300	R	2 9 W	2 39 W	3
8	„	6, 6	„	„	·997	225·3	10	7·35	7	300	R	2 17 W	2 40 W	4
9	Lacaille 2145	6, 6	6 2	48 27	·257	28·5	10	1·55	4	300	P	3 0 W	3 37 W	4
10	„	6, 6	„	„	·260	29·7	10	1·86	7	300	P	3 6 W	3 35 W	5
11	„	...	„	„	·263	29·3	6	...	...	300	P	3 54 W	4 23 W	3
12	„	...	„	„	·266	30·2	10	...	...	300	P	3 46 W	4 1 W	4
13	„	...	„	„	·301	30·6	10	...	...	300	P	3 59 W	4 22 W	3
14	„	7, 7	„	„	·304	31·4	10	1·50	6	300	P	3 41 W	4 9 W	4
15	Stone 4019	6, 8	7 54	47 36	·266	27·5	10	0·8	Est.	300	P	2 21 W	2 52 W	3
16	δ Argûs	3, 6	8 42	54 19	·285	156·1	8	...	...	535	...	1 38 E	1 10 E	

Ref. No.	Star.	Observed Magnitudes.	Approx. Place of Star 1895·0. R. A.	Approx. Place of Star 1895·0. Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.	Hour-angles.	Weight, 1 to 5.
			h m	° ′		°		″				h m	h m	
17	δ Argûs	4, 7	8 42	54 19	·301	165·7	10	...	...	535	P	3 22 W	3 48 W	4
18	”	3, 8	”	”	·449	157·3	10	...	...	535	P	1 36 W	2 19 W	5
19	”	3, 8	”	”	·457	162·4	10	...	...	535	P	4 17 W	4 43 W	4
20	α Crucis	...	12 21	62 31	·320	117·9	10	4·90	7	535	R	2 11 E	1 45 E	4
21	”	...	”	”	·334	117·6	7	...	...	535	R	1 55 E	1 18 E	3
22	γ Centauri	5, 5	12 36	48 23	·288	356·0	10	1·87	7	300	P	2 30 E	2 3 E	4
23	”	...	”	”	·301	355·2	10	2·06	7	300	P	1 23 E	0 56 E	4
24	”	...	”	”	·304	356·3	10	...	...	300	P	2 9 E	1 27 E	4
25	”	...	”	”	·304	355·8	10	1·60	10	535	P	2 9 E	1 27 E	4
26	”	...	”	”	·307	356·7	10	1·53	10	535	...	3 1 E	2 29 E	4 & 3
27	”	...	”	”	·315	356·0	10	...	...	300	P	3 19 E	2 31 E	5
28	”	...	”	”	·315	355·4	10	...	...	535				
29	”	...	”	”	·318	356·7	10	1·69	7	535	P	1 54 E	1 28 E	5 & 4
30	”	...	”	”	·320	356·1	10	1·68	6	300	P	2 54 E	2 33 E	4
31	”	...	”	”	·444	357·6	10	...	...	535	R	0 53 W	1 17 W	4
32	”	5, 5	”	”	·457	358·8	10	1·84	7	535	R	1 2 W	1 49 W	4
33	γ Virginis	...	12 36	0 52	·320	149·8	10	5·74	7	300	P	1 34 E	1 6 E	5
34	”	...	”	”	·397	149·9	10	6·15	6	300	P	0 59 E	0 35 E	4
35	β Muscæ	...	12 40	67 32	·288	335·4	10	1·60	7	300	P	3 26 E	2 51 E	3

Ref. No.	Star.	Observed Magnitudes.	Approx. Place of Star 1895·0. R. A.	Approx. Place of Star 1895·0. Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.	Hour-angles.	Weight, 1 to 5.
			h m	° ′		°		″				h m	h m	
36	β Muscæ	4½, 4½	12 40	67 32	·301	340·0	10	...	...	300	R	2 5 E	1 44 E	3
37	„	4½, 4½	„	„	·304	340·0	10	...	...	300	R	1 20 E	1 1 E	3
38	„	...	„	„	·307	337·8	10	...	...	300	...	3 53 E	3 12 E	4
39	„	...	„	„	·307	335·5	10	1·23	7	535				
40	„	...	„	„	·444	335·1	10	...	...	300	P	1 36 W	1 56 W	3
41	„	...	„	„	·457	337·0	10	...	...	535	P	1 59 W	2 27 W	4
42	α Centauri	...	14 33	60 24	·397	207·4	10	20·98	6	300	P	2 25 E	1 57 E	3
43	„	...	„	„	·400	207·6	10	20·82	10	300	P	2 54 E	2 20 E	4
44	„	...	„	„	·444	207·9	10	21·18	10	535	P	4 33 E	4 4 E	5
45	„	...	„	„	·446	208·0	10	20·89	10	535	P	3 5 E	2 23 E	4
46	„	1, 3	„	„	·449	207·4	10	...	...	300	P	4 36 E	4 25 E	5
47	„	...	„	„	·452	207·6	10	21·00	5	535	P	4 19 E	3 57 E	5
48	„	...	„	„	·452	207·4	10	...	...	535	P	1 35 E	1 15 E	4
49	„	1, 3	„	„	·457	207·7	10	20·89	8	535	P	2 18 E	1 47 E	5
50	„	1, 3	„	„	·487	207·9	6	...	...	535	P	3 24 E	3 9 E	4
51	„	1, 2	„	„	·630	208·5	10	20·78	8	300	R	2 24 W	2 57 W	3
52	„	...	„	„	·690	208·1	10	21·00	10	300	R	2 15 W	2 43 W	3
53	„	1, 2	„	„	·701	207·9	10	...	...	300	R	4 18 W	4 35 W	2
54	„	1, 3	„	„	·717	208·3	10	21·07	10	300	R	2 33 W	3 0 W	4

Ref. No.	Star.	Observed Magnitudes.	Approx. Place of Star 1895.0. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.		Weight, 1 to 5.
			h m	°		°		″				h m	h m	
55	α Centauri	...	14 33	60 24	·723	207·8	6	...	...	300	P	4 55 W	5 10 W	4
56	„	...	„	„	·726	207·6	10	...	...	300	R	1 12 W	1 30 W	2
57	„	...	„	„	·737	207·9	10	21·11	10	300	R	2 21 W	3 0 W	4
58	π Lupi	5, 5	14 58	46 38	·307	87·7	10	...	...	535	R	4 11 E	3 40 E	3
59	„				·307	87·0	10	...	...	300				4
60	„	4½, 4½	„	„	·318	87·7	10	1·53	6	300	R	3 41 E	3 18 E	4
61	„	5, 5	„	„	·630	86·4	10	1·64	8	300	R	2 55 W	3 24 W	4
62	„	5, 5	„	„	·633	86·7	10	1·66	5	300	P	1 23 W	1 58 W	4
63	ρ Ophiuchi	6, 7	16 19	23 12	·742	354·5	10	3·33	7	300	P	2 53 W	3 17 W	3
64	36 Ophiuchi	...	17 9	26 27	·742	195·3	10	4·72	6	300	R	1 3 W	1 26 W	4
65	Brisbane 6556	6, 6	18 54	37 12	·739	281·6	10	12·71	5	300	P	1 52 W	2 15 W	4
66	„	...	„	„	·742	281·3	10	12·67	5	300	R	2 26 W	2 49 W	4 & 3
67	Lacaille 7924	8, 8	„	63 56	·783	290·5	10	1·51	6	300	P	3 8 W	3 30 W	4 & 3
68	„	8, 8	„	„	·786	288·9	10	...	...	300	P	2 2 W	2 28 W	2
69	„	8, 8	„	„	·789	289·6	10	...	...	300	P	2 5 W	2 31 W	3
70	γ Coronæ Aust.	...	18 59	37 13	·717	162·5	10	...	...	300	R	1 20 W	1 43 W	3
71	„	...	„	„	·737	161·4	10	1·67	10	300	P	2 2 W	2 33 W	4
72	„	6, 6	„	„	·739	163·2	10	1·64	8	300	R	1 6 W	1 40 W	3
73	„	6, 6	„	„	·742	161·7	10	1·46	8	300	P	1 50 W	2 13 W	4

Ref. No.	Star.	Observed Magnitudes.	Approx. Place of Star 1895·0. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.		Weight, 1 to 5.
			h m	° ′		°		″				h m	h m	
74	γ Coronæ Aust.	...	18 59	37 13	·783	161·3	10	1·77	10	300	P	2 9 W	2 37 W	4
75	„	...	„	„	·789	159·4	10	...	...	300	P	2 41 W	3 1 W	3
76	θ Indi	5, 7	21 12	53 53	·871	281·8	10	4·45	7	300	P	2 8 W	2 37 W	4
77	„	5, 8	„	„	·917	283·1	10	4·45	8	300	R	3 47 W	4 16 W	2
78	θ Gruis	4½, 8	23 1	44 10	·830	29·3	10	...	...	300	R	1 19 E	0 58 E	2
79	„	...	„	„	·871	31·0	10	...	...	300	P	1 1 W	1 30 W	4
80	„	...	„	„	·936	21·1	10	...	...	300	P	2 14 W	2 38 W	1
81	„	4, 8½	„	„	·947	19·7	12	1·66	7	300	P	2 51 W	3 19 W	3
82	„	4, 8½	„	„	·961	31·2	10	...	...	300	R	3 20 W	3 48 W	2

Remarks.

In the column headed "Eyes" P denotes that the line joining the observer's eyes was parallel to that joining the components, and R that these lines were at right angles. The column headed "Hour-angles" gives the hour-angles between which the measures were made, and that headed "Weight" gives the value of each result on a scale of 1 to 5, 1 denoting the worst and 5 the best possible conditions.

The *following* component of No. 1 was the brighter. The components of Nos. 2, 3, 22, 27, 28, 30, 36, 60, 62, 65, 67, 68, 69, 70, 71, 72, 73, 74, 75, were noted to be equal. The south component of Nos. 9, 10, 35 was probably the brighter. The measures of Nos. 15, 16, 17, 18, 19, 78, 79, 80, 81, 82, were extremely difficult; the discrepancies in the results are due to the great inequality of the components and the faintness of the companions. Nos. 16 and 18 were measured in twilight; 44, 52, 64, partly in sunlight and partly in twilight; and 46, 47, 50, 54, 56, 57, in sunlight. Of No. 76 the primary was white and the companion blue, and of No. 78 the primary was yellowish and the companion bluish.

Windsor, N.S. Wales: 1896 January.

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the years 1894 *and* 1895.

(*Communicated by the Astronomer Royal.*)

The measures were made with a bifilar position micrometer on the 28-inch refractor. The power generally used was 670, but a power of 1030 was used when observing close pairs, and when the definition permitted. A blue glass shade was employed to diminish the light and irradiation, when bright stars were observed. The observers' initials in the last column, WC, D, M, L, H., WB, GEN, are those of Mr. Christie, Mr. Dyson, Mr. Maunder, Mr. Lewis, Mr. Hollis, Mr. Bowyer, and Mr. Niblett respectively. Fuller details of the observations will be published in due course in the Greenwich volumes for 1894 and 1895.

	Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer
			h m s	° ′	°	″				
Σ 3062	Bradley 3210		0 0 59	32 9	150·6	1·57	1	6·9 8·0	5·107	D.
			...	...	151·9	1·58	1	...	5·107	M.
OΣ 2		AB	0 8 11	63 36	30·8	0·49	2	6·9 8·3	5·857	L.
h 1007		AC	...	...	225·5	17·23	1	6·9 9·6	5·901	"
β 1027			0 9 44	69 3	180·5	1·38	1	7·7 11·5	5·901	"
*β 1093	Lalande 375		0 15 44	79 34	42·0	...	1	7·3 8·2	5·901	"
OΣ 20	66 Piscium		0 49 17	71 21	328·9	0·35	1	5·9 7·0	4·887	"
			...	...	335·0	0·32	2	...	5·895	"
Σ 73	36 Andromedæ		0 49 36	66 55	15·8	1·41	1	6·2 6·8	4·882	"
			...	...	11·2	1·28	3	...	5·904	"
β 1228	D.M. 12°·133		1 0 33	77 13	268·1	0·51	1	8·3 8·9	5·879	"
β 303			1 4 15	66 44	285·7	0·62	3	7·2 7·2	5·914	"
	φ Piscium		1 8 19	65 57	226·4	7·89	1	4·7 10·1	5·912	"
β 1029	ζ Piscium	BC	1 8 33	82 57	240·1	...	1	7·3 13·5	5·904	D.
Σ 113	42 Ceti		1 14 42	91 2	349·7	1·67	1	6·2 7·2	4·887	L.
β 1164	95 Piscium		1 22 28	84 10	162·4	0·43	2	6·7 7·0	5·492	"
β 506	η Piscium		1 26 8	75 10	25·0	0·63	1	4·0 10·5	5·879	"
β 507			1 30 21	63 44	156·9	2·16	1	8·0 11·0	5·868	"
Σ 138	Piazzi I. 123		1 30 49	82 52	37·5	1·51	2	7·3 7·3	5·916	"
Σ 155	W.B. (1) I. 666–7		1 38 57	81 1	327·6	4·83	1	7·5 7·9	5·904	D.

* Rough.

	Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer.
			h m s	° ′	°	″				
Σ 155	W.B. (1) I. 666–7		1 38 57	81 1	327·3	5·02	1	7·5 7·9	5·912	L.
β 509			1 38 28	80 56	257·5	0·74	1	8·4 8·7	5·912	„
Σ 158			1 40 59	57 20	256·9	2·11	1	8 3 8·8	5·868	„
β 510			1 43 9	74 10	333·9	2·08	1	8·1 10·5	5·901	„
Hough			1 45 40	65 50	351·3	0·36	1	7·5 7·7	4·887	„
			...	...	...	0·51	1	...	5·868	„
Σ 180	γ Arietis		1 48 2	71 12	0·9	8·53	1	4·2 4·4	5·868	„
β 512			1 48 18	71 13	292·0	1·25	1	8·6 11·7	5·868	„
Σ 183		AB	1 49 30	61 41	356·9	0·67	1	7·5 8·2	5·868	„
		AC	...	...	163·5	5·35	1	7·5 8 8	5·868	„
Σ 205	γ^1 Andromedæ		1 57 45	48 9	63·2	10·33	1	3·0 5·0	5·841	„
OΣ 38	γ^2 Andromedæ		1 57 46	48 9	286·6	...	3	5·0 6·2	5·872	D.
			...	..	291·3	0·21	5	...	5·907	L.
Σ 208	10 Arietis		1 57 59	64 33	62·3	1·03	1	6·2 8·4	5·868	„
Σ 228			2 7 37	43 1	69·4	0·37	3	6·7 7·6	5·869	„
β 876	A of Σ 258		2 17 57	56 57	233·6	1·00	1	7·7 11·9	5·868	„
		CD	...	...	33·7	6·14	1	8·9 9·2	5·868	„
β 262			2 41 45	59 22	239·7	1·59	2	8·2 9·6	5·896	„
β 525	Bradley 414		2 53 14	68 47	125·9	0·23	2	7·5 7·5	5·896	„
Σ 333	ε Arietis		2 53 29	69 4	202·3	1·39	2	5·7 6·0	5·896	„
β 1030			3 4 19	73 40	165·0	0·71	2	8·4 8·4	5·924	„

	Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No of Nights.	Magnitudes.	Epoch 1890+.	Observer.
			h m s	° ′	°	″				
Σ 412	7 Tauri		3 28 30	65 52	34·4	0·37	1	6·6 6·9	5·059	D.
			...	...	23·1	0·36	2	...	5·466	L.
OΣ 531	Piazzi III. 242		4 0 53	52 11	127·3	2·45	2	6·5 8·2	5·875	„
Σ 535			4 17 45	78 51	330·5	2·07	1	6·7 8·2	5·078	„
			...	...	328·5	1·68	1	...	5·876	D.
β 560			5 42 54	60 18	155·3	0·52	1	8·0 8·5	5·078	L.
Σ 1074	Piazzi VII. 81	AB	7 15 23	89 25	137·4	0·58	2	7·8 8·2	5·193	„
β 577		AC	...	...	106·1	14·15	1	7·8 13·5	5·192	„
Σ 1110	Castor		7 28 11	57 53	227·9	6·33	1	2·7 3·7	5·274	D.
			...	...	225·0	6·18	1	...	5·274	L.
OΣ 182			7 47 28	86 21	210·7	1·58	1	7·0 7·5	5·194	D.
			...	...	...	1·20	1	...	5·194	H.
			...	...	211·3	1·37	2	...	5·196	L.
β 581		AB	7 58 52	77 25	278·3	0·45	1	8·5 8·6	5·279	„
		AC	...	...	199·3	4·82	1	8·5 11·5	5·279	„
Σ 1196	ζ Cancri	AB	8 6 29	72 3	21·9	1·23	2	5·0 5·7	5·233	„
		AC	...	...	117·2	5·10	2	5·0 5·5	5·233	„
		BC	...	...	127·9	5·58	2	5·7 5·5	5·233	„
Σ 1263	Lalande 17161		8 38 36	47 56	20·6	51·42	1	7·6 8·2	5·296	„
†Σ 1273	ε Hydræ		8 41 29	83 13	231·4	3·74	1	3·8 7·8	5·230	„

† Definition bad.

	Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer.
			h m s	° ′	°	″				
Σ 3121			9 11 57	61 0	189·3	0·65	4	7·5 7·8	5·238	L.
OΣ 201			9 17 59	61 40	223·3	1·40	1	7·5 8·9	5·307	„
Σ 1348			9 19 13	83 13	319·5	1·63	1	7·5 7·6	5·307	„
Σ 1356	ω Leonis		9 23 5	80 30	108·4	0·72	1	6·2 7·0	5·192	„
Σ 1377	Piazzi IX. 161		9 38 17	86 55	138·3	3·68	1	7·9 11·1	5·186	„
Σ 1389			9 46 42	62 33	308·9	2·30	1	8·0 9·0	5·236	„
OΣ 215	Piazzi X. 23		10 10 49	71 46	209·0	1·01	3	6·7 7·0	5·239	„
Σ 1424	γ Leonis		10 14 7	69 39	114·2	3·64	4	2·0 3·5	5·226	„
			...	...	111·7	3·64	1	...	5·274	D.
Σ 1426		AB	10 15 17	83 4	282·3	1·00	1	7·8 8·3	5·279	L.
		AC	...	...	7·0	4·38	1	7·8 9·3	5·279	„
OΣ 224	Piazzi X. 128		10 34 29	80 38	321·4	0·47	2	7·2 9·2	5·228	„
OΣ 228			10 41 51	66 54	189·5	0·62	2	7·2 8·1	5·296	„
Σ 1504	Piazzi X. 229		10 58 49	85 49	282·0	1·56	1	7·5 7·6	5·282	D.
β 915			...	...	226·7	1·14	1	...	5·356	L.
Σ 1523	ξ Ursæ Maj.		11 12 52	57 54	176·0	1·98	1	4·0 4·9	5·326	„
Σ 1536	ι Leonis		11 18 42	78 54	58·2	2·54	2	3·9 7·1	5·280	„
Σ 1555	Piazzi XI. 111	AB	11 31 3	61 40	344·5	0·50	1	6·4 6·8	5·290	D.
			...	...	347·9	0·40	1	...	5·296	L.
		AC	...	...	146·3	21·64	1	6·4 10·3	5·296	„
β 603			11 45 25	75 5	...	1·05	1	...	5·205	D.

	Star's Name.	R.A. 1900. h m s	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer.
Σ 1639		12 19 26	63 52	277·1	0·28	1	6·7 7·9	5·236	L.
Σ 1658		12 30 2	82 0	355·4	2·40	1	8·0 9·8	5·279	,,
Σ 1661		12 30 57	78 2	237·3	2·52	1	8·5 8·5	5·350	,,
β 112	Piazzi XII. 243 BC	12 55 45	71 5	...	2·57	1	9·3 9·8	5·408	D.
		...	...	297·5	2·34	1	...	5·408	L.
OΣ 266	Lalande 24930	13 23 33	73 46	337·9	1·47	1	7·3 7·8	5·345	,,
β 612	B.A.C. 4559	13 34 38	78 42	213·6	0·43	1	6·4 6·5	5·323	,,
Σ 1785		13 44 32	62 31	262·2	1·44	1	7·2 7·5	5·460	,,
Σ 1877	ε Boötis	14 40 37	62 29	336·6	3·21	1	3·0 6·3	5·423	,,
Σ 1879		14 41 18	79 56	144·6	0·40	2	7·8 8·8	5·440	,,
Σ 1944		15 22 46	83 33	329·5	1·08	1	7·5 8·1	4·509	,,
Σ 1967	γ Coronæ Bor.	15 38 33	63 23	123·5	0·54	1	4·0 7·0	4·504	,,
Σ 2052		16 24 29	71 23	97·5	2·24	1	7·5 7·5	5·564	,,
Σ 2055	λ Ophiuchi	16 25 53	87 48	44·9	1·20	1	4·0 6·1	4·509	,,
		...	...	43·6	1·25	1	...	5·430	,,
Σ 2084	ζ Herculis	16 37 31	58 13	40·4	1·23	2	3·0 6·5	4·541	,,
		...	...	37·9	0·67	1	...	5·444	,,
Σ 2106		16 46 21	80 25	306·8	0·35	2	6·7 8·4	5·527	,,
Σ 2107		16 47 53	61 10	286·8	0·49	2	6·5 8·0	5·527	,,
Σ 2114	Piazzi XVI. 270	16 57 11	81 24	159·6	1·29	1	6·2 7·4	4·509	,,
		...	...	154·9	1·20	3	...	5·555	,,

Star's Name.			R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer.
			h m s	° ′	°	″				
Σ 2120			17 0 48	61 46	246·6	7·03	1	6·4 9·2	5·578	L.
Σ 2140	α Herculis		17 10 5	75 28	117·5	4·87	1	3·0 6·1	4·528	„
			...	...	115·8	4·98	1	...	5·515	„
Σ 2173			17 25 15	90 59	336·8	1·15	2	5·8 6·1	4·541	„
Σ 2205			17 40 6	72 14	308·3	2·15	1	8·3 8·7	5·611	„
β 631			17 34 47	90 36	69·8	0·37	1	7·5 7·6	5·682	„
Σ 2215			17 41 17	72 15	292·6	0·72	2	5·9 7·9	5·595	„
A.C. 7	μ Herculis	BC	17 42 33	62 13	42·9	1·46	1	10·0 10·1	5·482	„
OΣ 337	Piazzi XVII. 260		17 45 40	82 44	98·6	0·44	1	7·5 8·0	5·682	„
OΣ 338			17 47 27	74 39	17·2	0·81	2	6·6 6·9	5·666	„
			...	...	17·5	0·63	1	...	5·723	D.
Σ 2272	70 Ophiuchi		18 0 23	87 29	295·9	2·65	1	4·1 6·1	5·693	L.
A.C. 15	99 Herculis		18 3 14	59 28	293·4	0·34	2	6·0 11·5	5·652	„
Σ 2289			18 5 50	73 33	233·5	1·02	2	6·0 7·1	5·701	„
			...	...	233·3	1·24	1	...	5·723	D.
Σ 2315			18 21 0	62 40	199·6	0·24	1	7·9 8·6	4·531	L.
			...	...	222·9	0·37	2	...	5·527	„
			18 19 30	62 41	317·9	4·75	1	9·0 10·0	5·487	„
OΣ 357			18 31 15	78 21	252·5	0·34	1	7·5 7·6	5·660	„
OΣ 358			18 31 35	73 6	197·3	1·98	1	6·8 7·2	5·660	„
Σ 2400		AB	18 44 26	73 52	188·0	1·91	3	8·0 11·1	5·667	„

Star's Name.			R.A. 1900. h m s	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer.
Σ 2400		AC	18 44 26	73 52	194·4	3·12	3	8·0 11·0	5·667	L.
		AD	...	...	202·3	0·70	2	8·0 9·5	5·633	„
		AD	...	...	202·5	...	1	...	5·654	D.
Σ 2402			18 45 2	79 26	206·4	1·20	2	8·0 8·4	5·694	L.
β 648	B.A.C. 6480		18 53 14	57 14	237·9	1·49	3	6·0 9·8	5·590	„
Σ 2424	11 Aquilæ		18 54 28	76 31	263·6	16·97	1	5·7 9·2	5·687	„
			...	...	265·7	17·01	1	...	5·687	W.B.
			...	...	264·1	17·11	1	...	5·687	N.
Σ 2525			19 22 30	62 53	327·5	0·37	1	7·4 7·6	5·654	D.
			...	...	325·3	0·35	2	...	5·686	L.
Σ 2536			19 27 5	72 25	71·7	2·14	2	8·0 11·0	5·689	„
			19 27 20	72 9	141·0	4·54	1	10·0 11·0	5·720	„
Σ 2556			19 35 7	67 58	148·5	0·43	2	7·3 7·8	5·686	„
A.G.C. 11	ζ Sagittæ		19 44 32	71 6	171·7	0·24	2	4·5 6·0	5·686	„
Σ 2585		AC	...	...	312·0	8·81	1	...	5·715	„
O Σ 395	16 *h* Vulpeculæ		19 57 46	65 20	101·6	0·53	2	5·8 6·2	5·723	„
			...	...	99·6	0·57	1	...	5·726	D.
Σ 2695			20 27 41	64 32	81·6	1·07	3	6·2 8·0	5·722	L.
β 151	β Delphini		20 32 51	75 45	350·3	0·66	2	4·5 6·0	5·691	D.
		AB	...	...	351·9	0·65	1	...	5·813	L.
Σ 2704	β Delphini	AC	...	...	117·8	26·14	1	4·5 11·0	5·813	„

	Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer.
			h m s	° ′	°	″				
Σ 2704	β Delphini	AD	20 32 51	75 45	331·2	...	1	4·5 11·0	5·728	D.
		AD	...	...	331·0	36·66	1	...	5·813	L.
Σ 2729	4 Aquarii		20 46 8	96 0	191·8	0·20	1	5·9 7·2	5·813	„
Σ 2737	ε Equulei	AB	20 54 5	86 5	284·4	0·77	2	5·7 6·2	5·734	„
		AC	...	...	72·6	10·60	2	5·7 7·1	5·734	„
Σ 2744			20 57 58	88 52	168·3	1·40	1	6·3 7·0	5·737	„
Σ 2749		AB	20 59 43	86 52	156·6	2·77	1	7·7 8·9	5·737	„
		AC	...	...	154·6	4·43	2	...	5·712	„
		AD	...	...	153·0	0·59	1	...	5·737	„
		BC	...	...	154·6	1·07	1	...	5·737	„
Ho. 152			21 8 11	62 4	328·7	0·47	2	...	5·709	„
β 163			21 13 45	78 51	246·9	0·63	2	7·2 9·8	5·696	„
β 838			21 15 52	87 18	101·3	1·36	1	8·3 9·2	5·737	„
Σ 2799			21 24 1	79 19	119·4	1·22	4	6·6 6·6	5·717	„
			...	...	123·4	1·57	2	...	5·725	D.
Σ 2804			21 28 20	69 44	333·0	2·94	1	7·0 8·0	5·726	„
			...	...	331·9	2·97	2	...	5·732	L.
Σ 2822	μ Cygni		21 39 40	61 42	123·2	2·91	3	4·0 5·0	5·746	„
Σ 2824	κ Pegasi	AC	21 40 7	64 49	298·8	12·19	2	3·9 10·8	4·816	„
			...	...	298·9	12·24	2	...	5·689	„
β 989		AB	...	...	114·8	0·14	4	3·9 5·0	4·844	„

	Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Magnitudes.	Epoch 1890+.	Observer.
			h m s	° ′	°	″				
β 989	κ Pegasi	AB	21 40 7	64 49	104·1	0·12	5	3·9 5·0	5·705	L
			...	...	104·3	...	2	...	5·727	D.
			...	...	103·0	...	1	...	5·731	W.C.
			...	...	105·8	0·11	2	...	5·846	L.
			...	...	...	0·10	1	...	5 879	D.
β 75			21 50 40	79 35	37·0	1·14	3	8·1 8·3	5·755	L.
Σ 2849			21 53 2	70 16	264·0	1·41	2	8·2 10·7	5·732	,,
			21 53 0	69 42	85·1	2·13	1	...	5·726	,,
Σ 2878			22 9 32	82 31	126·5	1·19	4	6·5 8·c	4 826	,,
Σ 2881			22 10 0	61 55	101·3	1·58	2	7·7 8·2	5·712	,,
β 1216	Lalande 43605		22 15 37	60 59	312·5	0·52	3	8·4 8·7	5·746	,,
β 1218	W.B. (2) XXII. 476		22 23 28	60 49	52·8	1·76	2	8·6 8·8	5·775	,,
Σ 2900	33 Pegasi		22 18 50	69 39	176·9	1·69	1	6·0 9·2	5·737	,,
Σ 2934			22 37 0	69 8	150·2	1·00	1	8·2 9 2	5·731	,,
β 710			22 37 53	60 48	52·3	0·43	1	8·3 8·5	5·813	,,
β 80			23 13 42	85 9	325·1	0·63	1	8·1 8·7	4·846	,,
Hough	Σ 3002 = AB		23 15 43	88 6	202·5	4·10	1	7·9 10·7	4 846	,,
		AC	...	...	204·3	5·74	1	7·9 11·2	4·846	,,
	Hough = BC		...	...	213·5	0·89	1	10·7 11·2	4·846	,,
	85 Pegasi	AC	23 56 56	63 26	350·0	28·86	1	6·0 9·0	5·058	,,
β 733		AB	...	...	177·6	0·65	2	6·0 11·0	4·979	,,
			...	...	196·3	0·47	2	...	5·857	,,

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. APRIL 10, 1896. No. 7

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

William Anderson, Ballee House, Ballymena, co. Antrim, Ireland;
Thomas Frederick Furber, Trigonometrical Survey of New South Wales, Department of Lands, Sydney, Australia;
Frank L. Grant, M.A., 58 Kelvingrove Street, Glasgow;
Edward Ayearst Reeves, 24 Clyde Road, Wallington, Surrey;
George Frederick Herbert Smith, B.A., New College, Oxford; and
T. M. Teed, C.E., F.R.G.S., 188 Camberwell Grove, Denmark Hill, S.E.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Rev. Frederick Lisle Bullen, Littleton Rectory, Thornbury, Gloucestershire (proposed by W. F. Denning); and
Ernest W. Ellerbeck, Borough Meteorologist &c., Scarborough, Yorkshire (proposed by W. E. Plummer).

Sixty presents were announced as having been received since the last meeting, including amongst others:—

Rev. S. J. Johnson, "Historical and Future Eclipses," presented by the author; album containing a collection of autograph letters &c., from Sir G. B. Airy, Dr. J. R. Hind, Mr. J. W. Bosanquet, &c., relating to ancient eclipses, presented by Mr. Maw.

Note on Mr. Stone's Paper, "Expressions for the Elliptic Coordinates of a Moving Point to the Seventh Order of Small Quantities." By Professor Ernest W. Brown.

In the January number of the *Monthly Notices* Mr. Stone gives the expressions for the polar coordinates of a point moving in an ellipse about one focus, as far as quantities of the seventh order inclusive, with respect to the eccentricity and inclination. It may perhaps be useful to mention that these expressions are substantially contained in a memoir by Cayley, "Tables of the Developments of Functions in the Theory of Elliptic Motion" (*Memoirs R.A.S.* vol. xxix. 1861, pp. 191–306; *Coll. Works*, vol. iii. pp. 360–474). It is true that the expressions there given refer only to the case of motion in the plane of reference, but the steps necessary to obtain the longitude and latitude when the ellipse is inclined to the plane of reference require little more than the reading off of the coefficients from the tables.

The expressions for positive and negative powers of r/a are given on pp. 425–427 (*Coll. Works*), and that for the orbital elliptic longitude on p. 474.

To obtain the longitude in the plane of reference, we have, in Delaunay's notation,

$$\tan (V - h) = \cos i \tan \nu ;$$

whence

$$V - h = \nu - \tan^2 \frac{1}{2} i \sin 2\nu + \frac{1}{2} \tan^4 \frac{1}{2} i \sin 4\nu - \frac{1}{3} \tan^6 \frac{1}{2} i \sin 6\nu + \quad . \quad .$$

or

$$V = h + \nu - (\gamma^2 + \gamma^4 + \gamma^6) \sin 2\nu + \left(\frac{1}{2} \gamma^4 + \gamma^6\right) \sin 4\nu - \frac{1}{3} \gamma^6 \sin 6\nu + \quad . \quad . \quad (1)$$

Put

$$\nu = g + f,$$

where f is the true anomaly, and let

$$\cos jf = \Sigma_i \mathrm{A}_i \cos il, \qquad \sin jf = \Sigma_i \mathrm{B}_i \sin il,$$

where i, j are positive integers. We obtain

$$\sin j\nu = \frac{1}{2} \Sigma_i (\mathrm{A}_i + \mathrm{B}_i) \sin (jg + il) + \frac{1}{2} \Sigma_i (\mathrm{A}_i - \mathrm{B}_i) \sin (jg - il).$$

The coefficients

$$\frac{1}{2} (\mathrm{A}_i + \mathrm{B}_i), \qquad \frac{1}{2} (\mathrm{A}_i - \mathrm{B}_i)$$

are tabulated by Cayley * for all values of i, j from 1 to 7, as far as the order e^7 inclusive; so that the coefficient of any term in

* His notation differs from that used above.

V is obtained by taking out the part dependent on the eccentricity from the tables and multiplying it by the corresponding coefficient in (1).

To obtain the latitude, we have

$$\sin U = \sin i . \sin \nu;$$

whence (Hobson's *Trigonometry*, p. 268)

$$U = \sin i \sin \nu + \frac{1}{6}\sin^3 i \sin^3 \nu + \frac{3}{40}\sin^5 i \sin^5 \nu + \frac{5}{112}\sin^7 i \sin^7 \nu + \dots$$

Putting

$$\gamma = \sin\frac{1}{2}i,$$

this gives

$$U = \left(2\gamma - \frac{1}{4}\gamma^5 - \frac{3}{8}\gamma^7\right)\sin \nu - \left(\frac{1}{3}\gamma^3 + \frac{1}{4}\gamma^5 + \frac{1}{8}\gamma^7\right)\sin 3\nu$$
$$+ \left(\frac{3}{20}\gamma^5 + \frac{1}{4}\gamma^7\right)\sin 5\nu - \frac{5}{56}\gamma^7 \sin 7\nu + \dots$$

which is expanded, by means of Cayley's tables, in terms of sines of multiples of g, h and powers of e, γ, in the same way as the corresponding terms of the longitude.

It will be noticed that the coefficients of γ^7 in $\sin \nu$ and $\sin 3\nu$ differ from those obtained by Mr. Stone. He finds

$$+\frac{3}{8}\gamma^7 \sin(g+l), \qquad -\frac{3}{8}\gamma^7 \sin 3(g+l).$$

I obtain, by the above method, for these terms

$$-\frac{3}{8}\gamma^7 \sin(g+l), \qquad -\frac{1}{8}\gamma^7 \sin 3(g+l).$$

respectively. I have verified all the expressions and, with the exception of the terms just mentioned, find that the results agree. The fact that this verification occupied about half an hour will show the great convenience of Cayley's tables.

It may be mentioned that an evident typographical error occurs on p. 377 of the tables (*Coll. Works*, vol. iii.), where the coefficient $\frac{765}{1024}$, in the first line of the second column, is printed $\frac{768}{1024}$. This error is corrected by means of the three coefficients immediately below in the same column.

Haverford College, Pa.:
1895 *February* 24.

Note on Professor Brown's Note. By E. J. Stone.

Professor Brown is quite right in saying that the terms

$$\sin(g+l)\left[+\frac{3}{8}\gamma^7\right] \text{ and } \sin(3g+3l)\left[-\frac{3}{8}\gamma^7\right]$$

which appear on p. 113 in my paper, "Expressions for the Elliptic Coordinates of a Moving Point to the Seventh Order of Small Quantities," are incorrectly printed.

The first is simply an error of sign. The second has arisen from the coefficient found for sin $(g+l)$, $-\frac{3}{8}\gamma^7$, having been by inadvertence copied by me, when preparing the copy for press, into the argument for sin $(3g+3l)$, instead of $-\frac{1}{8}\gamma^7$.

The coefficients of the terms sin $(5g+5l)$ and sin $(7g+7l)$, which involve γ^7, and were found conjointly with those above-mentioned, are correctly printed.

Radcliffe Observatory, Oxford:
1896 *March* 16.

On the Relative Efficiency of a Reflector and of Portrait Lenses for the Delineation of Celestial Objects. By Isaac Roberts, D.Sc., F.R.S.

It has often been asserted that portrait lenses have, by reason of their short foci and relative apertures, greater photographic power than instruments constructed on other models, such as a reflector; but the assertion had not been confirmed, on any occasion, within my experience in the past. I therefore considered it desirable to submit the question to the test of some crucial experiments; the results of which shall now be laid before the Society.

The experiments were conducted in the manner following.

Two typical portrait lenses were purchased, of the best quality that could be obtained, and were affixed with their cameras firmly to the tube of the 20-inch reflector. The arrangements were such that three photographs of the same objects, by three different instruments, could be taken simultaneously under precisely and in every respect similar conditions.

The photo-plates were of the same degree of sensitiveness, the durations of the exposures were quite equal, and the development of the negatives was similar in all cases.

The photo-negatives thus obtained were examined; the stars upon equal and coincident areas on each plate were counted, including the faintest stars that could, by aid of a magnifier, be recognised as true star-images. The nebulosity also was compared on each corresponding plate, together with its extent, area covered, density, details, and every distinctive feature noted.

A portrait lens of the latest pattern, and of the most rapid combination, was obtained from Dallmeyer and Co. The aperture is $3\frac{1}{2}$ inches, and stellar focus 9·56 inches. The ratio of aperture to focus is therefore 1 to 2·74, and it covers, without much distortion, a photo-field of about 11 degrees in diameter.

Messrs. Cooke and Sons made specially for me a Taylor's triplet combination lens of 5 inches aperture and 19·22 inches stellar focus. The ratio of aperture to focus is therefore 1 to 3·84, and for these experiments it was used as 1 to 4·8. It covers a photo-field, without much distortion, of about 15 degrees in diameter. My experience of this lens is most satisfactory, and I think it will be difficult to improve upon it.

The reflector has an aperture of 20 inches, focus 98 inches, ratio of aperture to focus 1 to 4·9, and the photo-field is about $2\frac{1}{2}$ degrees in diameter.

The two lenses referred to were affixed, as already stated, upon the tube of the 20-inch reflector, so that a photograph with the $3\frac{1}{2}$-inch, the 5-inch, and the 20-inch instruments could be taken simultaneously, and under all the conditions of equality essential to a full and fair trial.

The results of the experiments may now be given, but in order to obviate too much repetition, I will give only three typical examples and illustrations, for they will be representative of the whole series.

We will first project on the screen a photograph of the region of M. 33 *Trianguli*, which was taken on November 14 last with the Dallmeyer $3\frac{1}{2}$-inch lens, and exposure of the plate during two hours and fifteen minutes. The circular photo-field shown is 11 degrees in diameter, and therefore contains 95 square degrees. In the centre of the circle are ruled four lines which enclose a rectangular space of four square degrees, and upon this area I counted 380 stars; and if we assume the stars to be equally numerous all over the field of 95 degrees there would be 9,025 stars upon it. The star-discs are round, sharply defined, and the faint ones small; the nebula is shown as a small patch or stain on the film, with very little detail and very few stars involved in it, and the plate all over is considerably fogged.

The next photograph, shown on the screen, was taken simultaneously with that just described, with the Cooke 5-inch lens. The circular field is 11 degrees in diameter, and represents 95 square degrees of the sky, which are coincident with those on the first photograph, and the four ruled lines also enclose identically the same area of four square degrees. Upon this area I counted 840 stars, and on the assumption of equal stars on equal

areas there would be 19,950 stars on the 95 degrees. The stars are round, sharply defined, and the faint ones small; a considerable extent of the spiral nebula is shown together with structural details and many of the faint and bright stars which are involved; the plate is free from any trace of fogging.

The third photograph, now shown, was taken with the 20-inch reflector simultaneously with the two already described, and it will be observed that the scale is large because of the larger instrument used. The area of the sky represented is only four square degrees, and is coincident with the areas that were shown on the first and second photographs, enclosed within the four lines referred to. I counted upon these four degrees 2,960 stars, and by the assumptions made and applied to the other two photographs there would be 70,300 stars on 95 square degrees. The nebula was described and illustrated before the Society at the meeting in December last, and I need not here repeat the description then given; suffice it to state that we have had projected upon the screen, and made evident to sight, demonstrations of the fact that on the reflector photograph the nebula is more extensively and clearly depicted, that it is at least two stellar magnitudes denser, and that far more of the structural details are shown than can be seen on the photographs taken with the portrait lenses.

The stars also are 3·52 times more numerous on the reflector photograph than on that by the 5-inch lens, and 7·78 times more numerous than on the photograph by the 3½-inch lens.

The examination of the nebulosity and the counting of the stars was in each of these cases done upon the original negatives.

The second series of the tests consists of three photographs of the region of γ *Cassiopeiæ*, which were taken simultaneously on 1895 December 13, with an exposure of the plates during two hours and twelve minutes.

The first, now exhibited, was taken with the Dallmeyer 3½-inch lens. The circular photo-field is 11 degrees in diameter, and therefore contains 95 square degrees. Upon an area of four square degrees with γ in the centre I counted 1,080 stars; and assuming, as in the other cases cited, that the stars are distributed equally over the plate, there would be 25,650 stars on 95 degrees. The photo-diameter of γ measures 18·7 minutes of arc, and the two fan-like nebulæ on the *north following* side are faintly shown but without structural details; the plate is fogged in irregular patches that might be easily mistaken for nebulosity.

The second photograph was taken with the Cooke 5-inch lens, and the circular field is 11 degrees in diameter, and represents 95 square degrees of the sky coincident with the first. Upon an area of four square degrees, corresponding with that on the first photograph, I counted 2,610 stars; and under the conditions already named there would be 61,987 stars on 95 degrees. The photo-diameter of γ measures 10·23 minutes of arc, and the two fan-like nebulæ, already referred to, are much more prominently

shown, together with some structural details and many of the involved stars; the plate is quite free from fogging effects and from spurious nebulosity.

The third photograph of this series is now shown; it was taken with the 20-inch reflector simultaneously and under precisely the same conditions as the first and second photographs just described; the photo-field is four degrees square, and upon this area I counted 17,100 stars; and again assuming equal stars on equal areas there would be 406,125 stars on 95 degrees. The photo-diameter of γ measures $16'\cdot9$ of arc; and the two fan-like nebulæ are very strongly and clearly shown with much structural detail; lights and shade; and lines and curves of stars involved making altogether not only a picture, but perpetuating each structural form, on a scale sufficiently large, for future scientific investigations and for the detection of any changes that must, some time or other, affect the character of the objects.

The stars are 6·55 times more numerous on the reflector photograph than on that by the 5-inch lens; and 15·93 times more numerous than by the $3\frac{1}{2}$-inch lens.

The examination of the nebulosity, and the counting of the stars was, in this and in the third series of tests, made upon the positive copies here exhibited, and not upon the negatives, for the reasons which will presently be given.

I may here state that the two fan-like nebulæ, which have been referred to, were faintly shown on a photograph of the region of γ which was taken with the 20-inch reflector on 1890 January 17, but at that time I thought they were due to stains on the film. The photo-plates were, in those days, less sensitive than they are now made.

The third series of the tests consists of three photographs of the region of the *Pleiades* which were taken simultaneously on 1896 February 4, with an exposure of the plates during two hours and fifty minutes.

The first, now exhibited, was taken with the Dallmeyer $3\frac{1}{2}$-inch lens; the circular photo-field is 11 degrees in diameter and contains 95 square degrees. Upon the area of four square degrees with η in the centre I counted 383 stars; and assuming, as in all the other cases cited, that the stars are distributed equally over the plate, there would be 9,100 stars on 95 degrees. The nebula round *Merope* is shown, but without any structural details and none of the other well-known nebulosities in the group can be seen. The disks of the bright stars are large and fuzzy, and the plate is much fogged.

The second photograph, now shown, was taken with the Cooke 5-inch lens; the circular field being 11 degrees in diameter and exhibiting 95 square degrees of the sky coincident with the first. Upon the area of four square degrees corresponding with that on the first photograph, I counted 953 stars; and upon 95 degrees there would be 22,600 stars. The *Merope* nebula is well shown and with some detail; so also are the other prominent

nebulosities in the group, and the plate is free from halation effects and fog. There is no indication of other nebulosity on other parts of the 95 degrees.

The last photograph of the series was taken with the 20-inch reflector, simultaneously with the two just described, and it exhibits four square degrees upon which I counted 3,470 stars; and upon 95 degrees there would be 82,400 stars. The stars are slightly elongated, but all the now known nebulosities are densely and brightly shown; crowded with details and free from halation and fog.

The stars are 3·64 times more numerous on the reflector photograph than on that by the 5-inch lens; and 9·06 times more numerous than by the $3\frac{1}{2}$-inch lens.

In all the experiments which I have made, the nebulosity, shown on the plates taken with the reflector, is denser than that by the portrait lenses in the ratio, approximately, of the relative number of faint stars shown on the plates which have been simultaneously exposed in the three instruments; and the illustrations which have been exhibited are proofs of the justness of this inference.

The results of the experiments herein described prove conclusively the greater efficiency of the reflector form of instrument over the portrait-lens or refractor form, for certain work in celestial photography; and it is not probable that refractors having shorter foci to apertures than 1 to 2·74 and 1 to 4·8, such as were used in these experiments, can, with greater perfection, be made of 20 inches aperture and 98 inches focus, so as to give better comparative results than those herein recorded.

These experiments also point to a practical limit of aperture to focus in the construction of instruments for celestial photography; and that the limit lies very nearly as 1 to 5; for I have consistently found a deterioration in the stellar images below aperture of 1 to 4; and apertures above 1 to 6 are slower in photographic effect.

Much misapprehension exists concerning the stellar image as seen in a telescope, and the photo-image as seen on a plate; it arises from the confusion of the ideas of points and surfaces of light. The telescopic image may be a point, but the photo-image is a measurable surface of chemical effect, spread on the sensitised film; and partakes of the character of nebulæ of small dimensions. As such, they must be subject to a rule which is not applicable to the visual telescopic image.

It follows from this that it is not possible, as it has been asserted, that a photographic instrument of the portrait lens form can imprint on the film images of nebulæ that are fainter than the faintest star-images imprinted at the same time and under exactly similar conditions.

The deductions which I have so far made are based upon the performances of lenses of a high character; but the ordinary portrait lenses are largely affected with imperfections producing

what are known as ghosts, and flares, in addition to fogging; therefore those who engage in stellar photography should first satisfy themselves that their lenses are free from these defects, and, above all, be careful that their plates are efficiently backed with some substance that will prevent reflections of the light from bright stars causing nebulous circles of halation on the film.

As illustrations of some of these defects, and also in further confirmation of the reliability of the results already given respecting the reflector and the portrait lenses, I will refer to some photo-positives on glass which are to be seen in the Library of the Society. They were taken by Professor Barnard at the Lick Observatory with what is described as the "Willard" lens, which has an aperture of 6 inches, and focus of 30·82 inches; the ratio of aperture to focus is therefore 1 to 5·14.

I shall refer only to three of these photographs, which are typical of the whole series. (1) The region of γ *Cassiopeiæ* was photographed on 1894 February 2, with an exposure of the plate during three hours; the photo-field is about 13½ degrees in diameter, of which about 11 degrees are fairly free from distortion. γ is seen in the middle of a halation circle of about 28 minutes of arc in diameter; and the two fan-like nebulæ are shown, but with little if any structural details and only a few of the involved stars are visible. I counted 1,300 stars on 2° by 2° with γ in the centre, and this area coincides with the respective areas of four square degrees which have already been described and illustrated, when referring to the photographs taken with the two lenses and the reflector.

The results of the comparison of this photograph with the others are as follows:—

3½-inch lens; focus 2·74; exposure 132 minutes; 1,080 stars on 2° by 2°; the two nebulæ are visible but without structural details.

5-inch lens; focus 4·8; exposure 132 minutes; 2,610 stars on 2° by 2°; the nebulæ are well shown and some of the involved stars also.

6-inch Willard lens; focus 5·4; exposure 180 minutes; 1,300 stars on 2° by 2°; the two nebulæ are shown with some of the stars involved in them, but with less density and clearness than by the 5-inch lens.

20-inch reflector; focus 4·9; exposure 132 minutes; 17,100 stars on 2° by 2°; the two nebulæ are brilliantly shown, with structural details, and many stars both bright and faint involved in the nebulosity.

The other two photographs to which I shall refer are of the region of the *Pleiades*, taken with the Willard lens: one with an exposure of 4 hours on 1893 December 1, and the other with an exposure of 10½ hours on 1893 December 6–8.

That with 4 hours' exposure shows the *Merope* nebula, but without any structural details; and there is a part of the projecting nebula from *Electra*; but all the rest of the nebulosity in

the group is lost in the halation circles which surround each of the bright stars, and none of the distant nebulosity is shown. I counted on four square degrees, with η in the centre, 825 stars as against 953 on the 5-inch lens plate, and 3,470 stars on the reflector plate; the exposure of the two last named being $2^h\ 50^m$ against 4^h with the Willard lens.

The plate exposed during 10½ hours shows only 1,385 stars on 2° by 2°, whilst the same area on the 4^h plate has 1,259 stars; therefore the difference in photo-effect upon the two plates is less than that of one stellar magnitude. This fact throws some doubt upon the reality of the distant nebulosity which is shown on the plate; and when we consider that the whole patch, that covers the group of the *Pleiades*, is due to halation, and not to nebulosity, the doubt is further strengthened.

The star images on this photograph are double and overlap; the exposures of the plate, therefore, were effectively of less than 10½ hours' duration.

Photograph of the "Owl" Nebula M 97 and of the Nebula H V 46 *Ursæ Majoris.* By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula M 97, R.A. $11^h\ 8^m\ 42^s$, Decl. 55° 36′ (epoch 1895), and of H V 46, R.A. $11^h\ 5^m\ 22^s$, Decl. 56° 15′ north, was taken with the 20-inch reflector on 1895 April 20, with an exposure of the plate during four hours, and the copy now presented is enlarged to the scale of 1 millimetre to 15 seconds of arc.

The nebula M 97 is N.G.C. No. 3587, G.C. No. 2343, *h* 838. Rosse, *Obs. of Neb. and Cl. of Stars*, p. 93, and *Phil. Trans.* 1850, Pl. XXXVII. fig. 11.

Sir J. Herschel (G.C. 2343) describes it as a very remarkable object, a planetary nebula, very bright, very large, round, very, very gradually, then very suddenly brighter in the middle, $19^s{\cdot}0$ in diameter. It is figured in the *Phil. Trans.* 1833 as a circle, stippled without any details.

Lord Rosse (cited above), in 1850, figured the nebula as a circle filled in with details somewhat resembling the face of an owl, with hair-like projections round the margin; and between the years 1848 and 1874 records the particulars of forty-five observations which were made. In some of them both he and Dr. Robinson saw a faint star to the right of the central star, and suspected the existence of one or two other very faint stars, as well as a spiral shape, but he does not refer to the hair-like surroundings of the nebula.

The photograph, now projected on the screen, shows the nebula as an ellipse with the major axis in *north following* to *south preceding* direction: it measures about 203 seconds of arc

in length. The star in the centre is very conspicuous, and of about 15th magnitude; but there is no other star anywhere in the nebula, though there are two very faint condensations of nebulosity near the *north preceding* margin. The nebula seems as if it consisted of two nebulous disks superposed: the first a complete circular plane of faint nebulosity upon which is superposed a broad ring of dense nebulosity of lesser diameter than the plane and leaving uncovered an elliptical space, in the centre, in the middle of which is placed the star already referred to.

The ring is not of equal breadth all round, but is widened on the *north following* and *south preceding* sides, and narrowed on the *south following* and *north preceding* sides; there is an absence of structure in the nebulosity, and the photograph does not indicate any nebulous projections beyond the symmetrical outline of the nebula. The disappearance of the second star, seen both by Lord Rosse and Dr. Robinson, is remarkable.

Photograph of the Nebula H V 46 *Ursæ Majoris.*
By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula H V 46 *Ursæ Majoris*, R.A. $11^h\ 5^m\ 22^s$, Decl. $56°\ 15'$ north, was taken with the 20-inch reflector on 1895 April 20, with exposure of the plate during four hours, and the copy now presented is enlarged to the scale of 1 millimetre to 15 seconds of arc.

The nebula is N.G.C. No. 3556, G.C. No. 2318, *h* 831. Rosse, *Obs. of Neb. and Cl. of Stars*, pp. 92, 93.

Sir J. Herschel (G.C. 2318) describes the nebula as considerably bright, very large, very much extended in the direction 79°, pretty bright in the middle, resolvable.

Lord Rosse records seven observations made between 1850 and 1874, and calls it a curiously twisted nebula, a large faint and much mottled ray with three stars involved; numerous stars involved; but much uncertainty in his observations is frequently indicated.

The photograph, as will be seen on the slide now projected on the screen, shows the nebula as an ellipse viewed at an acute angle with its plane, the major axis being in the direction of *preceding* and *following* at an angle of 79°, as stated. Four well-defined stars of 14th to 16th magnitude are involved in the nebulosity, and, besides, there are six star-like condensations involved; the nebulosity which forms the rings is much broken up into masses, and the nebula seems to be one of the class in which we might expect, within a comparatively short period, to detect changes taking place in its structure.

Photograph of the Cluster ℍ VII 66, *and of the Nebula* ℍ IV 75 *Cephei.* By Isaac Roberts, D.Sc., F.R.S.

The photograph of the cluster ℍ VII 66 *Cephei*, R.A. $21^h\ 43^m\ 24^s$, Decl. 65° 17′ north, was taken with the 20-inch reflector on 1895 September 25, with an exposure of the plate during three hours, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The cluster is N.G.C. No. 7142, G.C. No. 4709, *h* 2134. Rosse, *Obs. of Neb. and Cl. of Stars*, p. 163.

It is described by Sir J. Herschel (G.C. 4709) as considerably large, considerably rich, pretty compressed, stars 11th to 14th magnitude.

The photograph is in agreement with the general descriptions given, and, in addition, shows each star in the cluster in true relative position and magnitude down to about the 17th. The chief use of the photograph will be as a reliable record for future comparison of the stars in the cluster and in the surrounding region of the sky.

Photograph of the Nebula ℍ IV 75 *Cephei.*

The photograph of the nebula ℍ IV 75 *Cephei*, R.A. $21^h\ 40^m\ 34^s$, Decl. 65° 37′ north (epoch 1895), was taken with the 20-inch reflector on 1895 September 25, with exposure of the plate during three hours, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The nebula is N.G.C. No. 7129, G.C. No. 4702, *h* 2131. Rosse, *Obs. of Neb. and Cl. of Stars*, p. 162.

Sir J. Herschel (G.C. 4702) describes the nebula as a remarkable object, considerably faint, pretty large, gradually brighter in the middle, with three stars involved.

The photograph shows the nebula to be elliptical, measuring 432″ in *north following* to *south preceding* direction, and 285″ in *south following* to *north preceding*. The nebulosity is dense on the *north following* side, and involved in it, as a nucleus, are the three stars referred to by Sir J. Herschel: two of them are of about 12th magnitude and the third 16th magnitude. There are also eleven other stars, ranging between the 12th and 17th magnitudes, apparently involved in the nebula. The character of the nebulosity is flocculent with extensive dark areas, but there is some structure visible near the *north following* margin.

There are three stars, each of about 13th magnitude, surrounded by very faint nebulosity in the positions following, measured from the centre of the tristellar nucleus of the nebula: (1) 358″ *north following*; (2) 326″ *north preceding*; (3) 277″ *north preceding*. The stars Nos. 2 and 3 are not referred to in Dr. Dreyer's catalogues, and the measurements given above are approximate.

Observations of the Variable Stars W, X, and Y Sagittarii.
By Lieut.-Colonel E. E. Markwick.

The following observations were made at Gibraltar with a binocular field-glass magnifying about five times, and are in continuation of those appearing at p. 338 vol. lv. of the *Monthly Notices.*

W Sagittarii. Thirty-five observations, the star being compared with 14 (U.A.) *Sagittarii,* 5·4 mag. In the table, the first column gives the date of observation for identification. The second is the day and hour of observation reduced to G.M.T., and converted into Julian days and fraction. The next column is the observed magnitude. Maxima were calculated from Dr. Chandler's formula—viz.

$$1866 \text{ Sept. } 4 = 240\ 2849{\cdot}45 + 7{\cdot}59460\ E.$$

With the other data in Chandler's second catalogue—viz. variation 4·8 to 5·8 and $M - m = 3{\cdot}00\ d$—a typical curve was drawn (see *Monthly Notices,* vol. liv. p. 138), and the observations plotted on the same scale. The distance of each observation from the curve horizontally was then measured off in fractions of a day, those to the left of the curve being negative, and *vice versa.*

The fourth column gives the interval in days elapsed between date of observation and next preceding maximum. The last column gives the distances just referred to. Remarks from observing book are added.

W Sagittarii.

Date. 1895.	Julian 2,410 000d + d	Observed brightness.	After maximum. d	O−C. d
July 13	3388·42	5·6	5·26	−0·3
14	89·44	5·4	6·28	+0·4
15	90·42	4·95	7·26	+0·4
17	92·39	4·9	1·64	+0·9
17	92·44	5·0	1·69	+0·5
18	93·46	5·25	2·71	+0·6
19	94·44	5·5	3·69	+0·9
20	95·45	5·8	4·70	+0·2
21	96·41	5·7	5·66	+0·5
22	97·38	4·7	6·63	−1·0
22	3397·43	5·0	6·68	−0·1
26	3401·39	5·45	3·04	+0·4
27	02·43	5·6	4·08	+0·8
30	05·38	4·8	7·03	−0·5
Aug. 7	3413·35	4·6	7·41	−0·2

Date. 1895.	Julian 2,410,000d+ d	Observed brightness.	After maximum. d	O–C. d	
Aug. 11	3417·43	5·6	3·89	+0·7	
12	18·38	5·5	4·84	–0·9	
12	18·40	5·6	4·86	–0·6	
16	22·43	5·3	1·30	–0·9	
17	23·43	5·3	2·30	+0·1	
24	30·42	5·1	1·69	0·0	
Sept. 8	45·33	5·2	1·41	–0·5	
9	46·38	5·6	2·46	–0·8	Clouds about.
29	66·32	4·8	7·21	–0·4	Moon.
Oct. 4	71·30	5·5	4·60	–1·1	Twilight.
7	74·30	5·1	0·01	–1·6	
9	76·30	5·3	2·01	–0·2	
10	77·32	5·4	3·03	+0·5	
11	78·32	5·7	4·03	+0·4	
14	81·31	4·9	7·02	0·0	
16	83·29	5·3	1·40	–0·8	
18	85·32	5·8	3·43	–1·0	
30	3497·27	4·9	0·19	–0·5	Bright moonlight.
Nov. 2	3500·28	5·2	3·20	+1·2	Twilight and Moon.
3	3501·28	5·5	4·20	+1·4	

From the last column we get as the sum of 16 positive residuals 9·9 days, and of 17 negatives 11·4 days. Combining these with the observations of 1893 and 1894, we get the following result:

	No. of Observations		Sum of	
	with Positive Residuals.	with Negative Residuals.	Positive Residuals. d	Negative Residuals. d
1893	16	22	10·0	14·5
1894	10	14	5·1	12·5
1895	16	17	9·9	11·4
Total	42	53	25·0	38·4

We therefore get 0·60 day as the average value of a positive, and 0·72 day as the average value of a negative residual. On the whole, it seems that the period of 7·59460 days is correct, and the star's variation conforms very regularly to it.

X Sagittarii. Thirty-four observations, treated as in the previous case. Comparison star F 4 *Sagittarii* 5·4 *m.* Chandler's data for this star are—

Elements of maximum 1870 Aug. 16 = 240 4291·78 + 7·01185 E.

Variation 4 to 6. M – *m* = 2·876*d.*

X Sagittarii.

Date. 1895.	Julian 2,410,000 d +	Observed brightness.	After maximum. d	O—C. d	
July 13	3388·42	5·4	2·27	−0·5	
14	89·44	5·7	3·29	0·0	
15	90·42	5·8	4·27	+0·8	
17	92·39	4·5	6·24	−0·7	
17	92·44	4·9	6·29	−0·1	
18	93·46	4·9	0·30	−1·2	
19	94·44	5·1	1·28	−0·8	
20	95·45	5·35	2·29	−0·4	Careful estimate.
21	96·41	5·7	3·25	0·0	
22	97·38	5·6	4·22	+1·2	"Bilious!"
22	3397·43	5·7	4·27	+1·0	
26	3401·39	5·0	1·22	−0·5	Moon.
27	02·43	5·2	2·26	0·0	
30	05·38	5·7	5·21	−0·3	Moon.
Aug. 7	13·35	5·7	6·17	+0·7	
11	17·43	5·1	3·24	+1·2	
12	18·38	5·6	4·19	+1·2	
12	18·40	5·7	4·21	+1·0	
16	22·43	4·7	0·23	−0·4	
17	23·43	5·1	2·23	+0·2	
24	30·42	5·5	2·20	−0·7	
Sept. 8	45·33	5·2	3·09	+0·8	
9	46·38	5·95	4·14	−0·1	Clouds about.
29	66·32	5·6	3·05	0·0	Moon.
Oct. 4	71·30	5·2	1·01	−1·3	
7	74·30	5·4	4·01	+1·3	
9	76·30	5·0	6·01	−0·2	
10	77·32	4·8	0·02	−1·1	
11	78·32	5·0	1·02	−0·7	
14	81·31	5·7	4·01	+0·7	Levanter wind.
16	83·29	5·4	5·99	+0·2	
30	3497·27	5·6	5·94	+0·3	Bright moonlight.
Nov. 2	3500·28	5·4	1·94	−0·8	Observation difficult. Moon and twilight.
3	01·28	5·9	2·94	−1·1	

From the last column we get as the sum of 13 positive residuals 10·6 days, and of 17 negative 10·9 days. Combining

these with the observations of 1893 and 1894, we get the following:

	No. of Observations with Positive Residuals.	No. of Observations with Negative Residuals.	Sum of Positive Residuals.	Sum of Negative Residuals.
1893	25	14	7·2	22·8
1894	5	16	1·8	16·2
1895	13	17	10·6	10·9
Total	43	47	19·6	49·9

Hence for the three years

Average value of a positive residual = 0·46 day

" " negative " = 1·06 day

The observations for 1895 cluster closely round the typical curve, and support it better than those of the two preceding years. In fact, if the most probable curve were drawn among the 1895 observations, independently, I think that such curve would be found to approximate very closely to the pattern light curve. Hence no correction to the period given above seems required.

Y Sagittarii. Compared with 45 (U.A.) of *Sagittarius*, 6·5m, 26 observations in 1894, 41 in 1895. Those for 1893 are in vol. xiii. p. 180 of the *Astronomical Journal.* They are treated as before, the data being

1886 Sept. 25 = 241 0175·02 + 5·7732 E.

Variation 5·7 to 7·0. M − m = 1·80d.

Y Sagittarii.

Date. 1894.	Julian 2 410 000d + d	Observed brightness.	After maximum. d	O−C. d	
Aug. 20	3061·41	5·8	5·56	+0·1	
25	66·39	6·6	4·77	+1·0	
26	67·39	6·2	0·00	+0·9	
27	68·33	6·2	0·94	−1·1	Twilight.
27	68·37	6·4	0·98	−1·4	
28	69·38	6·5	1·99	−0·5	
Sept. 4	76·39	6·6	3·22	+0·6	
20	92·38	6·7	1·89	−0·9	Clouds about.
21	93·33	6·8	2·84	−0·3	
22	94·32	6·6	3·83	−0·8	
22	94·38	6·75	3·89	−0·6	
25	97·32	6·55	1·06	−1·4	
25	97·37	6·7	1·11	−1·8	

Date.	Julian 2 410,000d +	Observed brightness.	After maximum.	O−C.	
1894.	d		d	d	
Sept. 26	3098·31	6·8	2·05	−1·0	
29	3101·31	6·6	5·05	+0·5	
Oct. 1	03·31	6·7	1·28	−1·6	
2	04·32	6·7	2·29	−0·6	
4	06·31	6·9	4·28	−0·1	
4	06·37	6·8	4·34	−0·1	
21	23·30	7·0	3·95	0·0	
22	24·28	6·4	4·93	+0·2	
24	26·31	6·5	1·18	−1·4	
27	29·30	6·8	4·17	−0·3	
29	31·31	6·3	0·41	−1·6	
31	33·30	6·7	2·40	−0·5	
Nov. 16	3149·27	6·3	1·05	−1·1	Bright twilight.
1895.					
July 13	3388·41	6·15	3·49	−1·5	
14	89·44	6·1	4·52	−0·6	
15	90·43	5·75	5·51	−0·1	
17	92·39	5·9	1·70	+0·7	
17	92·44	6·1	1·75	+0·1	
18	93·47	6·5	2·78	+0·3	
19	94·44	6·7	3·75	−0·8	
20	95·45	6·5	4·76	0·0	
21	96·41	5·7	5·72	0·0	
22	97·38	5·5	0·98	+1·0	
22	97·43	5·9	0·96	−0·1	
26	3401·43	6·2	4·96	0·0	
27	02·43	5·9	0·19	−0·9	
30	05·38	6·4	3·14	+0·9	Moon.
Aug. 7	13·35	5·8	5·34	−0·1	
11	17·43	6·4	3·65	−1·2	
12	18·38	6·6	4·60	−0·1	
12	18·40	6·5	4·62	−0·1	
16	22·43	6·3	2·87	+0·7	
17	23·42	6·45	3·86	−1·0	
24	30·41	6·6	5·08	+0·5	
Sept. 9	46·38	6·6	3·73	+1·0	Clouds about.
29	66·28	6·1	0·54	−1·1	Moon.
Oct. 4	71·30	6·0	5·56	+0·4	

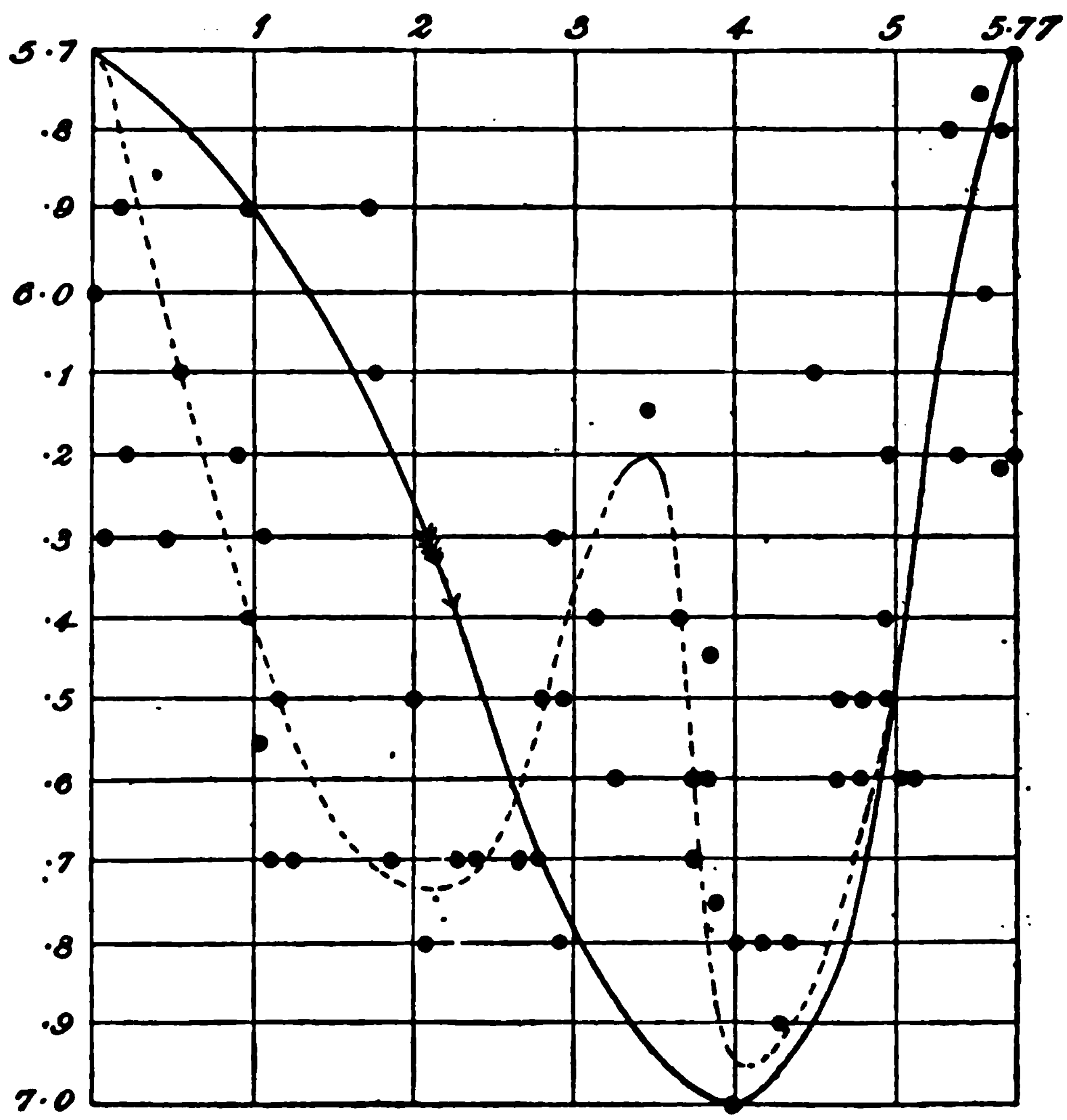
Date. 1894.	Julian 2,410,000d+ d	Observed brightness.	After maximum. d	O–C. d	
Oct. 7	3474·31	6·7	2·80	0·0	
9	76·30	6·6	4·79	+0·1	
10	77·31	6·3	0·02	−2·1	
11	78·32	6·3	1·03	−1·1	
14	81·31	6·8	4·02	−0·5	
16	83·29	6·2	0·23	−1·6	
18	85·32	6·7	2·26	−0·6	
27	94·31	6·2	5·47	+0·5	Doubtful observation.
30	3497·27	6·7	2·66	−0·2	
Nov. 2	3500·28	6·22	5·67	+0·7	
3	01·28	6·2	0·90	−1·1	
5	03·29	6·5	2·91	+0·4	
7	05·30	6·5	4·92	+0·2	Clouds about.
8	06·28	6·0	0·02	−1·3	Clouds about.
12	10·27	6·8	4·11	−0·3	
13	11·30	6·6	5·14	+0·4	Getting very low.
16	3514·28	6·7	2·36	−0·5	

	No. of Observations		Sum of	
	with Positive Residuals.	with Negative Residuals.	Positive Residuals.	Negative Residuals.
1893	22	19	9·7	9·0
1894	19	6	3·3	17·1
1895	22	15	7·9	16·9
Total	63	40	20·9	43·0

Therefore for the three years

Average value of positive residual = $0·33d$.
" " negative " = $1·07d$.

I attach a drawing of the 1894–95 observations plotted to scale. In several cases the dots fall twice on the same place. An inspection shows that many of the observations cluster very closely round the rising branch, while in the descending branch the dots seem to be more scattered. On the whole, I do not think that for the present any further approach to accuracy could be gained by an alteration of the period. If lengthened or shortened the typical curve would be shifted either to the right or left, and it is plain that either of these movements, although bringing the curve into closer proximity to *some* dots, would yet leave others at a further distance from it. The same argu-



ment applies to a possible systematic error in estimating the star's brightness. In this case the typical curve must go either up or down vertically. Neither of such movements would on the whole, I think, bring it into any better relation to the dots. Neither would a better correspondence be produced by shifting the minimum phase—*i.e.* altering M—*m*. Therefore the adopted period would seem correct.

If, however, in future years the negative residuals go on increasing, it will be necessary to consider a slight diminution of the period.

It is just possible that a secondary maximum is indicated, occurring about 3·3 days after the principal one. I have shown this by a dotted line. Although I am diffident as to the objective reality of the supposed phenomenon, I place it on record here. The observations of future years will settle the question.

The three stars which have been dealt with all appear to belong to the same class, *S* 10 *Sagittæ* being a representative in the northern hemisphere. It is difficult to account for variation of this nature. Whether it be due to eclipses by one or more opaque attendants, to unequal brilliancy of successive portions of the visible disk as presented to the Earth at time of observa-

tion, or to changes in the brilliancy of the star's photosphere—whatever it be due to—the remarkable regularity with which the light waxes and wanes must be always taken into account in the theory, at once differentiating this class from the long-period variables which are subject to great irregularities in their periods.

Gibraltar: 1896 February 3.

Melbourne Observatory.

The following letter and report were received by the Secretaries on April 13, too late for inclusion in the Annual Report of the Council:—

" *Observatory, Melbourne:*
" *1896 March 10.*

"Dear Sir,—I am sending you herewith a Report of our work in 1895. The very long delay was unavoidably caused by my absence from the Observatory.

" Believe me, very truly yours,
"Pietro Baracchi.

The Secretary, Royal Astr. Society, London."

The following is a brief account of the work carried out at the Melbourne Observatory during the year 1895:—

Meridian Work.—Observations in Right Ascension 2,503, in North Polar distance 1,387, subdivided as follows: viz. 819 observations of standard clock stars, 255 of azimuth stars, 54 special stars observed three times in both coordinates for the Adelaide Observatory, and the remainder, observations of stars for use in connection with our astrophotographic work. With regard to the latter stars it may be stated here that they were taken from a list, which we are gradually completing, consisting of stars selected from the catalogue plates in the zone allotted to this observatory (five stars in each plate suitably distributed for the purpose of facilitating the final reduction of these plates), and intended for observation with the transit circle. 195 of these stars have also been observed at the Adelaide Observatory and Sir Charles Todd has promised further help in this direction. The transit circle was reversed in 1895 March.

Astrophotographic Work.—Number of exposed plates 397, subdivided as follows: viz. catalogue plates 236, chart plates 49, Oxford type charts 26. Plates exposed on the pole for testing the clearness of the night 53, plates for trails 22, for adjustment of the centre 11. Of these 17 were rejected on account of defects in the film, setting, or broken exposure. Each plate was submitted to a preliminary examination in order to ascertain that the general conditions, such as accurate setting, orientation,

intensity of images of minimum magnitude stars, definition, &c., were satisfactory; and also for the selection and measurement of the five stars mentioned above. These measurements are made by a micrometer scale (of the type proposed by Professor Turner) made by Troughton and Simms. It works satisfactorily in so far at least as these preliminary measures are concerned. Only 139 plates remain to be taken in the zone allotted to Melbourne, and these will be secured in the course of this year.

Time Service.—On 1895 February 1, zone time referred to the meridian 10^h east of Greenwich was inaugurated in the Colony of Victoria, and accordingly since then the time-ball has been caused to drop $20^m\ 6^s$ earlier than formerly. Zone time signals were transmitted to town and up-country telegraph and railway stations as usual.

Magnetical.—The photographic curves representing the variation of the elements of terrestrial magnetism have been secured throughout the year with only a few hours of accidental interruption. Absolute measurements were made about once a month.

Meteorological Service.—Two forecasts of the weather were issued daily. Rainfall statistics and weather records have been prepared for the press in quarterly publications as in preceding years. Photographs of the Sun were taken on 58 days.

Miscellaneous.—Testing of nautical, surveying, and meteorological instruments, and rating of chronometers for the public. This formed part of our routine work throughout the year. 350 visitors were attended to on Wednesday afternoons, and 247 were admitted at night to view the moon, &c. through the great telescope.

General Remarks.—In March last Mr. E. F. J. Love, M.A., Lecturer on Physics at the Melbourne University, returned to Melbourne after a visit to England, during which he swung the three half-second pendulums of this observatory at Greenwich, Kew, and Cambridge, for gravity determinations. It was necessary to again swing these pendulums after the voyage in order to ascertain their invariability. This was done, and from a preliminary reduction of my observations made here before and after Mr. Love's trip to England, it appears that no appreciable change took place in the instruments. Mr. Love is now engaged in making a fresh determination of the pressure and temperature corrections, after which the final reductions will be made and the results published.

Very few observations were made with the great telescope and smaller equatorial. The examination of the southern nebulæ, for which the great telescope is almost solely adapted (apart from celestial photography), was suspended in 1892, owing to reorganisation of the staff, necessitated by the retirement of the first and second assistants, Messrs. White and Moerlin. The work had been in my charge for the previous eight years, and at the end of that time many hundreds of drawings, sketches, and descriptions of nebulæ, with micrometric measurements of neighbouring

stars were added to those of previous observers. These were intended to be arranged in proper form and reduced for publication as a sequence to part I. of *Observations of Southern Nebulæ, &c.*, edited by Mr. Ellery, but circumstances prevented the carrying out of this purpose.

It would now seem undesirable, even if time could be spared for this most attractive class of astronomical observations, to continue the work on nebulæ, until we have dealt with the material already secured.

Other still unpublished works are the Melbourne zones 60° to 69° 20′ south declination, observed between 1866 and 1871, and the annual catalogues 1884–94 inclusive, all fully reduced.

In April last Mr. Fred Ingamells, one of the junior assistants who had given valuable services for 12 years, retired in pursuance of a retrenchment scheme proposed by the Government.

Mr. Ellery's voluntary retirement from the post of Government astronomer, which, as has already been notified, took place in July last, was a loss to the observatory which cannot be overrated, and will be felt for a long time. Thus in the last three years the staff has been severely weakened by the retirement of four workers, including its oldest and most experienced members and its director. It is, however, intended to keep the meridian and astrophotographic work up to the usual standard of past years.

The meteorological work which weighs so heavily on the time and energy of the institution can hardly be reduced, as the public demands it with increasing exigency.

The magnetic work cannot be discontinued, as this is the only station in Australia where such observations are systematically carried out. Indeed, there seems to be a revival of general interest in terrestrial magnetism with some prospect of concerted observations being undertaken, and no doubt the co-operation of this observatory, where records have been continuously taken for over 30 years, seems all the more desirable.

The investigation of the division errors of the 8″ transit circle has not yet been made. It is fully recognised that a catalogue based upon the observations made with this instrument since 1884 cannot be completed until such investigation is accomplished. The question of measurement and reduction of the astrophotographic plates has not yet been seriously considered. It is hoped that at the forthcoming conference of the International Committee to be held at Paris in May next, some understanding may be arrived at as to the course to be adopted for this purpose.

Note on Comet Perrine (1895 *IV*). By Dr. H. Kreutz.

(*Communicated by the Secretaries.*)

The following letter has been received from Dr. Kreutz :—

"*Kiel:* 1896 *April* 18.

"In *Monthly Notices*, 1896 March, theilt Herr H. C. Russell die Beobachtung eines Cometen von A. E. Parker d. d. 1895 Dec. 21–24, mit. Es ist nun gar kein Zweifel, dass es sich hier um eine Beobachtung des ersten Cometen Perrine handelt; vergl. die Mittheilung aus Dar-es-Salaam *Astr. Nachr.* 3339, p. 47, und *The Observatory*, 1896 Jan., p. 62."

Further Note on the Light seen at Oxford on 1896 *March* 4. By H. H. Turner, M.A., B.Sc., Savilian Professor.

In the letter above quoted Dr. Kreutz continues :—

"Eine ganz ähnliche Erscheinung, wie Sie am 4. März d. J. sahen, ist auch von uns vor längerer Zeit (1895 März 13) in Kiel in W.N.W. beobachtet worden. Hier aber konnte Prof. Lamp, der sich auf dem höchst gelegenen Punkt der Sternwarte befand, constatiren, dass es sich um einen Nordlichtstrahl handelte. Von unten aus gesehen, war die Erscheinung, welche circa ¼ Stunde andauerte, dem Schweife eines grossen Cometen täuschend ähnlich."

Mr. Charles Martin, Assistant at Dunsink, writes me as follows :—

"*Dunsink House, co. Dublin:*
"1896 *April* 19.

"I saw in *The Observatory* that you read a paper on zodiacal light seen by you on March 4. I was observing that night here, and watched the light for about two minutes. It was 5° wide, and stretched from the horizon to about 40° N.P.D. I only saw it for two minutes, as thick clouds came up and hid it. It was in the N.W. by W. I thought myself that it was clouds at a great distance above the other clouds, but could not make much out of it, as it clouded up soon after I noticed it. Time, 8.30 P.M., Irish time."

Observations of Comet a 1896 (Perrine-Lamp) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log Factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log Factor of Parallax.	No. of Comps.	Appt. R.A.	Appt. N.P.D.	Comp. Star.
1896. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Mar. 12 11 9 24	H.	+1 43·28	0·00	9·7094	+4 0·8	+0·2	0·7904	4	3 1 44·35	41 25 32·1	*a*
12 11 9 24	”	−1 40·67	−0·01	9·7094	+8 27·7	+0·4	0·7904	4	...	...	*b*
12 11 33 46	”	−3 55·29	−0·01	9·6867	+3 30·0	+0·2	0·8180	2	3 1 53·26	41 26 7·9	*c*
22 8 1 58	B.	−0 55·76	0·00	9·6684	−4 54·1	0·0	0·5007	3	...	...	*d*
22 8 2 37	”	−1 55·85	0·00	9·6690	+0 54·1	0·0	0·5021	4	3 49 39·99	45 9 0·4	*e*
23 8 42 25	”	+0 21·04	−0·01	9·6960	−5 35·1	0·0	0·5855	5	3 52 56·54	45 27 8·4	*f*
23 9 5 1	”	+0 24·24	0·00	9·7063	+3 44·2	0·0	0·6262	4	3 52 59·44	45 27 20·2	*g*
Apr. 1 8 55 5	A. C.	−1 55·00	0·00	9·6923	−2 10·5	0·0	0·6509	2	4 15 11·09	47 32 5·2	*h*
1 8 55 19	”	−2 8·77	0·00	9·6922	+1 14·8	0·0	0·6513	6	4 15 12·04	47 32 15·4	*k*

Notes.

The observations are corrected for refraction but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

March 12.—Observations rather uncertain. Comet getting low (zenith distance 68°), and much fainter.

March 22.—Comet extremely faint. Bright moonlight. Observations difficult and uncertain.

March 23.—Bright moonlight. Comet still fainter than on previous day. Only seen by glimpses.

April 1.—Comet still easily visible, but rather ill-defined.

The initials H., A C., B., are those of Mr. Hollis, Mr. Crommelin, and Mr. Bryant respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1896·0. h m s	Assumed N.P.D. 1896·0. ° ′ ″	Authority.
a	BD + 48°, No. 849	3 0 1·19	41 21 48·2	Bonn Astr. Gesell. Catalogue.
b	BD + 48°, No. 857	3 3 25	41 17	Bonn Observations, vol. v.
c	Lalande 5851	3 5 48·62	41 22 55·1	Bonn Astr. Gesell. Catalogue, Paris Catalogue 1875, and Annual Catalogue 1882.
d	BD + 44°, No. 819	3 50 36	45 14	Bonn Observations, vol. v.
e	BD + 44°, No. 822	3 51 35·56	45 8 22·8	Bonn Astr. Gesell. Catalogue.
f	BD + 44°, No. 828	3 52 35·23	45 32 59·7	,, ,, ,,
g	BD + 44°, No. 827	3 52 34·93	45 23 52·3	,, ,, ,,
h	BD + 42°, No. 952	4 17 5·72	47 34 30·9	,, ,, ,,
k	BD + 42°, No. 954	4 17 20·44	47 31 15·8	,, ,, ,,

Lalande 5851.—The R.A. of this star, in Paris Annual Catalogue for 1882, has been increased by 0ˢ·80 in accordance with a communication from M. Tisserand.

Royal Observatory, Greenwich:
1896 *April* 9.

Ephemeris for Physical Observations

Greenwich Noon.	P.	L−O.	B.	A−L.	*B*.	Q.	E.
1896. May 20	332°98	95°542	−24°88	−42°90	−20°52	245°62	39°66
22	332·25	97·188	24·77	43·24	20·84	245·64	39·90
24	331·54	98·827	24·64	43·57	21·15	245·67	40·13
26	330·86	100·460	24·49	43·88	21·45	245·71	40·36
28	330·19	102·086	24·32	44·18	21·74	245·77	40·58
30	329·54	103·704	−24·14	−44·47	−22·03	245·84	40·80
June 1	328·92	105·313	23·94	44·74	22·30	245·93	41·01
3	328·32	106·914	23·72	45·00	22·56	246·03	41·22
5	327·74	108·507	23·49	45·25	22·81	246·15	41·43
7	327·19	110·090	23·24	45·48	23·04	246·28	41·64
9	326·66	111·662	−22·97	−45·69	−23·27	246·43	41·84
11	326·15	113·223	22·69	45·89	23·49	246·59	42·04
13	325·67	114·773	22·40	46·07	23·69	246·76	42·23
15	325·21	116·311	22·09	46·24	23·88	246·94	42·42
17	324·78	117·838	21·77	46·39	24·06	247·14	42·60
19	324·37	119·353	−21·44	−46·52	−24·22	247·35	42·78
21	323·99	120·856	21·09	46·64	24·37	247·58	42·95
23	323·63	122·346	20·73	46·75	24·51	247·82	43·12
25	323·30	123·823	20·36	46·84	24·64	248·06	43·28
27	323·00	124·288	19·98	49·92	24·76	248·32	43·44
29	322·72	126·740	−19·58	−46·98	−24·86	248·59	43·60
July 1	322·47	128·179	19·17	47·03	24·95	248·88	43·75
3	322·24	129·605	18·76	47·06	25·03	249·17	43·90
5	322·03	131·018	18·34	47·08	25·09	249·48	44·04
7	321·85	132·417	17·91	47·08	25·14	249·79	44·18
9	321·70	133·803	−17·47	−47·08	−25·18	250·12	44·31
11	321·57	135·175	17·03	47·06	25·20	250·46	44·43
13	321·46	136·533	16·58	47·03	25·21	250·81	44·55
15	321·38	137·877	16·12	46·98	25·21	251·16	44·66
17	321·32	139·207	15·65	46·92	25·20	251·53	44·77
19	321·29	140·523	−15·18	−46·86	−25·17	251·90	44·87
21	321·28	141·825	14·71	46·78	25·13	252·28	44·96
23	321·29	143·114	14·23	46·69	25·07	252·67	45·05

of Mars, 1896–97. By A. Marth.

Greenwich Noon.	Brightness.	Appar. Diam.	Defect of Illumination q	Equat.	Polar.	Central Meridian. ω_0	Passage of Zero Meridian.	
1896.	m	″	″	″	″	°	h m	h m
May 20	0·97	6·15	0·71	0·71	0·00	207·52	10 27	11 8
22	0·95	6·20	·72	·72	·00	187·68	11 49	12 29
24	0·94	6·24	·73	·73	·00	167·84	13 10	13 51
26	0·93	6·28	·75	·74	·00	148·01	14 32	15 13
28	0·92	6·32	·76	·75	·01	128·19	15 54	16 35
30	0·90	6·37	0·77	0·76	0·01	108·38	17 15	17 56
June 1	0·89	6·41	·79	·77	·01	88·58	18 36	19 17
3	0·88	6·45	·80	·78	·01	68·78	19 58	20 38
5	0·87	6·50	·81	·79	·02	48·99	21 19	22 0
7	0·86	6·55	·83	·80	·02	29·21	22 40	23 21
9	0·84	6·59	0·84	0·81	0·02	9·45	...	0 2
11	0·83	6·64	·85	·82	·02	349·69	0 42	1 23
13	0·82	6·69	·87	·83	·03	329·94	2 4	2 44
15	0·80	6·73	·88	·84	·03	310·21	3 25	4 5
17	0·79	6·78	·89	·85	·04	290·49	4 46	5 26
19	0·78	6·83	0·91	0·86	0·04	270·78	6 7	6 47
21	0·77	6·88	·92	·86	·04	251·08	7 28	8 8
23	0·75	6·93	·94	·87	·05	231·39	8 49	9 29
25	0·74	6·99	·95	·88	·05	211·72	10 10	10 50
27	0·73	7·04	·96	·89	·06	192·06	11 31	12 11
29	0·71	7·09	0·98	0·89	0·06	172·42	12 51	13 32
July 1	0·70	7·15	1·00	·90	·07	152·79	14 12	14 52
3	0·69	7·20	1·01	·91	·07	133·16	15 33	16 13
5	0·67	7·26	1·02	·91	·08	113·55	16 53	17 34
7	0·66	7·32	1·03	·92	·09	93·96	18 14	18 54
9	0·64	7·37	1·05	0·93	0·09	74·38	19 34	20 15
11	0·63	7·43	1·06	·93	·10	54·81	20 55	21 35
13	0·62	7·49	1·08	·94	·10	35·26	22 15	22 55
15	0·60	7·56	1·09	·94	·11	15·72	23 35	...
17	0·59	7·62	1·10	·95	·11	356·20	0 15	0 55
19	0·57	7·68	1·12	0·96	0·12	336·69	1 36	2 16
21	0·55	7·75	1·13	·96	·13	317·19	2 56	3 36
23	0·54	7·82	1·15	·97	·13	297·71	4 16	4 56

Greenwich Noon.		P.	L−O.	B.	A−L.	*B*.	Q.	E.
1896.		°	°	°	°	°	°	°
July	25	321·32	144·389	13·75	46·59	25·00	253·07	45·13
	27	321·37	145·651	13·27	46·48	24·93	253·47	45·21
	29	321·44	146·899	−12·78	−46·36	−24·84	253·88	45·28
	31	321·54	148·133	12·29	46·23	24·74	254·30	45·34
Aug.	2	321·66	149·354	11·80	46·09	24·62	254·72	45·39
	4	321·79	150·561	11·30	45·95	24·49	255·15	45·43
	6	321·94	151·754	10·81	45·80	24·36	255·58	45·47
	8	322·11	152·932	−10·32	−45·64	−24·21	256·02	45·50
	10	322·29	154·096	9·83	45·47	24·05	256·46	45·52
	12	322·49	155·245	9·34	45·29	23·87	256·90	45 53
	14	322·71	156·380	8·85	45·10	23·69	257·35	45·53
	16	322·94	157·500	8·35	44·91	23·50	257·80	45·52
	18	323·19	158·606	− 7·88	−44·71	−23·29	258·25	45·50
	20	323·45	159·697	7·40	44·50	23·08	258·70	45·47
	22	323·72	160·773	6·93	44·28	22·85	259·15	45·43
	24	324·00	161·835	6·46	44·06	22·62	259·60	45·38
	26	324·30	162·881	5·99	43·83	22·37	260·05	45·32
	28	324·60	163·912	− 5·53	−43·59	−22·12	260·50	45·24
	30	324·91	164·927	5·08	43·35	21·86	260·94	45·15
Sept.	1	325·23	165·925	4·63	43·10	21·59	261·38	45·05
	3	325·56	166·907	4·19	42·84	21·31	261·82	44·93
	5	325·90	167·871	3·75	42·56	21·02	262·26	44·80
	7	326·24	168·817	− 3·32	−42·28	−20·72	262·69	44·65
	9	326·58	169·745	2·91	41·99	20·42	263·11	44·49
	11	326·92	170·654	2·50	41·69	20·11	263·53	44·31
	13	327·27	171·543	2·11	41·38	19·79	263·94	44·11
	15	327·62	172·412	1·73	41·06	19·46	264·34	43·89
	17	327·97	173·261	− 1·35	−40·72	−19·13	264·73	43·65
	19	328·32	174·089	0·98	40·37	18·79	265·12	43·39
	21	328·66	174·895	0·63	40·01	18·45	265·49	43·11
	23	329·00	175·678	− 0·29	39·63	18·10	265·85	42·81
	25	329·34	176·437	+ 0·03	39·24	17·74	266·20	42·48
	27	329·67	177·171	+ 0·34	−38·83	−17·38	266·54	42·13
	29	330·00	177·880	0·63	38·40	17·01	266·86	41·75
Oct.	1	330·32	178·561	0·91	37·95	16·64	267·17	41·34
	3	330·62	179·214	1·18	37·49	16·26	267·46	40·91
	5	330·92	179·837	1·43	37·01	15·88	267·73	40·45
	7	331·20	180·429	+ 1·65	−36·50	−15·49	267 99	39·95

Greenwich Noon.		Brightness.	Appar. Diam.	Defect of Illumination q	Equat.	Polar.	Central Meridian. ω_0	Passage of Zero Meridian.	
1896.		m	"	"	"	"	°	h m	h m
July	25	0.52	7.88	1.16	.97	.14	278.24	5 36	6 16
	27	0.51	7.95	1.18	.98	.14	258.78	6 56	7 36
	29	0.49	8.03	1.19	0.99	0.15	239.34	8 16	8 56
	31	0.47	8.10	1.20	0.99	.16	219.91	9 36	10 16
Aug.	2	0.46	8.17	1.22	1.00	.16	200.49	10 56	11 36
	4	0.44	8.25	1.23	1.00	.17	181.09	12 15	12 55
	6	0.42	8.33	1.24	1.01	.17	161.70	13 35	14 15
	8	0.40	8.41	1.26	1.02	0.18	142.33	14 55	15 35
	10	0.39	8.49	1.27	1.02	.19	122.97	16 14	16 54
	12	0.37	8.58	1.28	1.03	.19	103.63	17 34	18 13
	14	0.35	8.66	1.30	1.04	.20	84.30	18 53	19 33
	16	0.33	8.75	1.31	1.04	.20	64.99	20 12	20 52
	18	0.31	8.84	1.32	1.05	0.21	45.69	21 32	22 11
	20	0.29	8.94	1.33	1.05	.21	26.41	22 51	23 31
	22	0.27	9.03	1.35	1.06	.22	7.14	...	0 10
	24	0.24	9.13	1.36	1.06	.22	347.89	0 50	1 29
	26	0.22	9.23	1.37	1.07	.23	328.65	2 9	2 48
	28	0.20	9.33	1.38	1.08	0.23	309.43	3 28	4 7
	30	0.18	9.44	1.39	1.08	.23	290.22	4 47	5 26
Sept.	1	0.15	9.55	1.40	1.09	.24	271.03	6 6	6 45
	3	0.13	9.66	1.41	1.09	.24	251.86	7 24	8 4
	5	0.10	9.78	1.42	1.10	.25	232.70	8 43	9 22
	7	0.08	9.90	1.43	1.10	0.25	213.56	10 2	10 41
	9	0.05	10.02	1.44	1.11	.25	194.44	11 20	12 0
	11	0.03	10.15	1.44	1.11	.25	175.34	12 39	13 18
	13	0.00	10.28	1.45	1.11	.26	156.26	13 57	14 36
	15	−0.03	10.41	1.45	1.12	.26	137.20	15 15	15 55
	17	−0.06	10.55	1.46	1.12	0.26	118.15	16 34	17 13
	19	−0.09	10.69	1.46	1.12	.26	99.13	17 52	18 31
	21	−0.12	10.83	1.46	1.12	.26	80.14	19 10	19 49
	23	−0.15	10.98	1.46	1.12	.26	61.16	20 28	21 7
	25	−0.18	11.14	1.46	1.12	.27	42.21	21 45	22 24
	27	−0.21	11.30	1.46	1.12	0.27	23.29	23 3	23 42
	29	−0.24	11.46	1.45	1.12	.27	4.39	...	0 21
Oct.	1	−0.28	11.63	1.45	1.12	.26	345.52	0 59	1 38
	3	−0.31	11.80	1.44	1.11	.26	326.67	2 17	3 56
	5	−0.35	11.97	1.43	1.11	.26	307.85	3 35	4 13
	7	−0.38	12.15	1.42	1.10	0.26	289.07	4 51	5 30

Greenwich Noon. 1896.		P.	L−O.	B.	A−L.	*B*.	Q.	E.
Oct.	9	331°·47	180°·988	1°·86	35°·96	15°·10	268°·23	39°·42
	11	331·73	181·514	2·05	35·40	14·71	268·44	38·85
	13	331·97	182·005	2·22	34·81	14·31	268·63	38·24
	15	332·19	182·459	2·36	34·20	13·91	268·80	37·60
	17	332·39	182·876	+ 2·48	−33·55	−13·51	268·95	36·92
	19	332·58	183·254	2·59	32·87	13·10	269·07	36·20
	21	332·74	183·591	2·67	32·16	12·69	269·16	35·44
	23	332·88	183·886	2·73	31·41	12·28	269·23	34·63
	25	333·00	184·137	2·76	30·62	11·86	269·26	33·77
	27	333·09	184·343	+ 2·77	−29·80	−11·44	269·26	32·87
	29	333·16	184·502	2·75	28·94	11·02	269·22	31·92
	31	333·20	184·613	2·71	28·03	10·60	269·15	30·91
Nov.	2	333·21	184·673	2·64	27·08	10·18	269·04	29·86
	4	333·20	184·683	2·54	26·09	9·75	268·88	28·75
	6	333·15	184·642	+ 2·41	−25·05	− 9·33	268·67	27·58
	8	333·08	184·549	2·26	23·97	8·90	268·42	26·36
	10	332·98	184·404	2·08	22·84	8·47	268·12	25·09
	12	332·85	184·206	1·87	21·66	8·04	267·76	23·76
	14	332·69	183·957	1·63	20·44	7·61	267·33	22·38
	16	332·50	183·659	+ 1·37	−19·17	− 7·18	266·82	20·95
	18	332·29	183·313	1·08	17·86	6·74	266·23	19·47
	20	332·05	182·919	0·77	16·50	6·31	265·54	17·93
	22	331·79	182·479	0·44	15·11	5·88	264·73	16·35
	24	331·51	181·997	+ 0·08	13·68	5·45	263·76	14·73
	26	331·21	181·476	− 0·29	−12·21	− 5·02	262·59	13·08
	28	330·89	180·919	0·67	10·71	4·58	261·13	11·39
	30	330·57	180·331	1·07	9·19	4·15	259·24	9·68
Dec.	2	330·23	179·716	1·48	7·64	3·72	256·66	7·95
	4	329·88	179·079	1·90	6·08	3·28	252·83	6·23
	6	329·53	178·426	− 2·32	− 4·50	− 2·85	246·34	4·53
	8	329·19	177·764	2·74	2·92	2·42	232·93	2·93
	10	328·85	178·098	3·16	− 1·33	1·99	197·57	1·77
	12	328·51	176·435	3·57	+ 0·24	1·56	136·09	2·20
	14	328·19	175·780	3·97	1·81	1·14	115·63	3·36
	16	327·88	175·138	− 4·36	+ 3·36	− 0·71	105·19	4·96
	18	327·58	174·515	4·73	4·88	− 0·28	99·76	6·60
	20	327·30	173·916	5·18	6·38	+ 0·14	96·41	8·24
	22	327·04	173·346	5·41	7·85	0·56	94·08	9·86

Greenwich Noon.		Bright-ness.	Appar. Diam.	Defect of Illumination q	Equat.	Polar.	Central Meridian. ω_0	Passage of Zero Meridian.	
1896.		m	″	″	″	″	°	h m	h m
Oct.	9	−0.42	12.34	1.41	1.09	.26	270.32	6 8	6 47
	11	−0.46	12.53	1.39	1.08	.25	251.60	7 25	8 4
	13	−0.50	12.72	1.37	1.06	.25	232.92	8 42	9 20
	15	−0.54	12.92	1.34	1.05	.25	214.27	9 58	10 37
	17	−0.58	13.12	1.32	1.03	0.24	195.66	11 15	11 53
	19	−0.62	13.33	1.29	1.01	.24	177.09	12 31	13 9
	21	−0.66	13.53	1.26	0.98	.23	158.56	13 48	14 26
	23	−0.70	13.74	1.22	0.96	.22	140.07	15 4	15 41
	25	−0.74	13.96	1.18	0.93	.21	121.62	16 19	16 56
	27	−0.79	14.18	1.13	0.90	0.21	103.22	17 34	18 12
	29	−0.83	14.39	1.09	0.86	.20	84.87	18 49	19 27
	31	−0.87	14.61	1.04	0.83	.19	66.56	20 4	20 42
Nov.	2	−0.92	14.83	0.99	0.79	.18	48.31	21 19	21 57
	4	−0.96	15.05	0.93	0.74	.17	30.10	22 34	23 11
	6	−1.01	15.26	0.87	0.70	0.15	11.94	23 48	...
	8	−1.05	15.47	.80	.65	.14	353.84	0 25	1 2
	10	−1.09	15.67	.74	.60	.13	335.78	1 39	2 16
	12	−1.14	15.87	.67	.55	.12	317.78	2 53	3 30
	14	−1.18	16.06	.60	.50	.10	299.83	4 7	4 44
	16	−1.22	16.24	0.54	0.44	0.09	281.92	5 20	5 57
	18	−1.26	16.41	.47	.39	.08	264.07	6 33	7 10
	20	+1.30	16.56	.40	.34	.06	246.26	7 46	8 23
	22	−1.34	16.70	.34	.29	.05	228.49	8 59	9 36
	24	−1.38	16.82	.28	.24	.04	210.76	10 12	10 48
	26	−1.41	16.93	0.22	0.19	0.03	193.07	11 25	12 1
	28	−1.44	17.01	.17	.15	.02	175.42	12 37	13 13
	30	−1.47	17.07	.12	.11	.01	157.80	13 49	14 25
Dec.	2	−1.50	17.11	.08	.08	.01	140.20	15 1	15 37
	4	−1.52	17.12	.05	.05	.00	122.62	16 13	16 49
	6	−1.54	17.11	0.03	0.03	...	105.06	17 25	18 1
	8	−1.56	17.07	.01	.01	...	87.50	18 37	19 13
	10	−1.56	17.01	.00	.00	.00	69.95	19 49	20 25
	12	−1.54	16.92	.01	...	.01	52.39	21 1	21 37
	14	−1.50	16.81	.01	.00	.01	34.82	22 13	22 49
	16	−1.46	16.68	0.03	0.01	0.02	17.24	23 25	...
	18	−1.41	16.53	.05	.03	.02	359.63	0 1	0 37
	20	−1.36	16.36	.08	.05	.03	342.00	1 14	1 50
	22	−1.31	16.16	.12	.08	.04	324.34	2 26	3 2

Greenwich Noon.		P.	L–O.	B.	A–L.	*B*.	Q.	E.
1896. Dec.	24	326°79	172°808	5°72	9°28	0°98	92°36	11°44
	26	326·57	172·305	– 6·00	+ 10·68	+ 1·40	91·00	12·98
	28	326·37	171·840	6·25	12·04	1·82	89·90	14·48
	30	326·19	171·416	6·48	13·35	2·24	88·98	15·93
1897. Jan.	1	326·03	171·037	6·68	14·61	2·65	88·20	17·33
	3	325·89	170·704	6·86	15·83	3·07	87·54	18·67
	5	325·77	170·417	– 7·01	+ 17·00	+ 3·48	86·97	19·95
	7	325·68	170·178	7·13	18·12	3·89	86·48	21·18
	9	325·61	169·987	7·22	19·19	4·30	86·06	22·35
	11	325·55	169·844	7·29	20·21	4·70	85·69	23·46
	13	325·52	169·749	7·33	21·18	5·10	85·38	24·52
	15	325·50	169·701	– 7·34	+ 22·10	+ 5·50	85·11	25·52
	17	325·51	169·699	7·33	22·98	5·90	84·89	26·47
	19	325·53	169·741	7·29	23·81	6·30	84·71	27·36
	21	325·57	169·826	7·23	24·60	6·69	84·56	28·20
	23	325·62	169·953	7·14	25·34	7·08	84·45	29·00
	25	325·69	170·120	– 7·03	+ 26·04	+ 7·47	84·37	29·75
	27	325·78	170·327	6·91	26·70	7·85	84·32	30·45
	29	325·88	170·572	6·76	27·32	8·23	84·30	31·10
	31	326·00	170·853	6·60	27·91	8·61	84·30	31·71
Feb.	2	326·14	171·170	6·42	28·46	8·99	84·33	32·28
	4	326·29	171·520	– 6·21	+ 28·98	+ 9·36	84·38	32·81
	6	326·45	171·902	5·99	29·46	9·73	84·45	33·30
	8	326·63	172·315	5·76	29·92	10·10	84·55	33·75
	10	326·83	172·758	5·51	30·34	10·47	84·67	34·17
	12	327·04	173·229	5·25	30·73	10·83	84·81	34·56
	14	327·27	173·726	– 4·97	+ 31·10	+ 11·19	84·96	34·92
	16	327·51	174·248	4·68	31·45	11·54	85·13	35·24
	18	327·76	174·794	4·38	31·87	11·89	85·32	35·53
	20	328·03	175·363	4·06	32·07	12·24	85·52	35·80
	22	328·31	175·953	3·73	32·35	12·58	85·74	36·04
	24	328·60	176·564	– 3·39	+ 32·60	+ 12·92	85·97	36·26
	26	328·91	177·195	3·05	32·84	13·26	86·22	36·45
	28	329·23	177·844	2·69	33·06	13·60	86·48	36·62
Mar.	2	329·57	178·511	2·32	33·26	13·93	86·75	36·77
	4	329·92	179·196	1·95	33·45	14·25	87·03	36·89
	6	330·28	179·899	– 1·57	+ 33·62	+ 14·57	87·32	36·99

Greenwich Noon.	Bright-ness.	Appar. Diam.	Defect of Illumination q	Equat.	Polar.	Central Meridian. ω_0	Passage of Zero Meridian.			
1896.	m	″	″	″	″	°	h	m	h	m
Dec. 24	−1·26	15·69	·16	·11	·05	306·65	3	39	4	15
26	−1·20	15·74	0·20	0·14	0·06	288·92	4	51	5	28
28	−1·14	15·50	·25	·17	·07	271·15	6	4	6	41
30	−1·08	15·26	·29	·21	·08	253·34	7	17	7	54
1897.										
Jan. 1	−1·00	15·01	·34	·24	·09	235·48	8	31	9	7
3	−0·96	14·75	·39	·28	·10	217·57	9	44	10	21
5	−0·90	14·48	0·44	0·31	0·11	199·62	10	58	11	35
7	−0·84	14·22	·48	·35	·12	181·62	12	12	12	49
9	−0·78	13·95	·52	·39	·13	163·57	13	26	14	3
11	−0·71	13·68	·57	·42	·14	145·47	14	40	15	17
13	−0·65	13·41	·61	·45	·14	127·32	15	54	16	32
15	−0·59	13·14	0·64	0·48	0·15	109·12	17	9	17	47
17	−0·53	12·88	·68	·51	·16	90·88	18	25	19	2
19	−0·47	12·62	·71	·53	·16	72·59	19	40	20	17
21	−0·41	12·36	·73	·55	·16	54·26	20	55	21	33
23	−0·35	12·11	·76	·57	·17	35·88	22	10	22	48
25	−0·29	11·86	0·78	0·59	0·17	17·46	23	26	...	
27	−0·23	11·62	·80	·61	·17	359·00	0	4	0	42
29	−0·18	11·38	·82	·62	·17	340·51	1	20	1	58
31	−0·12	11·15	·83	·63	·18	321·98	2	36	3	14
Feb. 2	−0·06	10·92	·84	·64	·18	303·41	3	52	4	30
4	−0·01	10·70	0·85	0·65	0·18	284·80	5	9	5	47
6	0·04	10·49	·86	·66	·18	266·17	6	25	7	3
8	0·10	10·28	·87	·66	·18	247·50	7	42	8	20
10	0·15	10·08	·87	·67	·18	228·80	8	59	9	37
12	0·20	9·89	·87	·67	·18	210·08	10	16	10	54
14	0·25	9·70	0·87	0·67	0·18	191·33	11	33	12	11
16	0·30	9·51	·87	·67	·17	172·55	12	50	13	29
18	0·35	9·33	·87	·67	·17	153·75	14	7	14	46
20	0·39	9·16	·87	·66	·17	134·93	15	24	16	3
22	0·44	8·99	·86	·66	·17	116·09	16	42	17	21
24	0·48	8·83	0·85	0·66	0·17	97·22	17	59	18	38
26	0·53	8·67	·85	·65	·16	78·33	19	17	19	56
28	0·57	8·52	·84	·65	·16	59·42	20	35	21	14
Mar. 2	0·61	8·38	·83	·64	·16	40·50	21	52	22	31
4	0·65	8·23	·82	·64	·16	21·56	23	10	23	49
6	0·69	8·09	0·81	0·63	0·15	2·60	...		0	28

Greenwich Noon.	P.	L−O.	B.	Λ−L.	*B*.	Q.	E.
1897. Mar. 8	330°66	180°617	1°18	33°78	14°89	87°63	37°07
10	331·05	181·350	0·78	33·92	15·21	87·95	37·14
12	331·45	182·098	− 0·37	34·05	15·52	88·28	37·19
14	331·86	182·860	− 0·04	34·16	15·83	88·61	37·22
16	332·29	183·635	+ 0·45	+ 34·26	+ 16·13	88·95	37·24
18	332·73	184·422	0·87	34·36	16·43	89·30	37·24
20	333·18	185·221	1·30	34·44	16·72	89·66	37·23
22	333·64	186·032	1·73	34·51	17·01	90·03	37·21
24	334·12	186·855	2·17	34·57	17·30	90·40	37·17
26	334·61	187·689	+ 2·61	+ 34·62	+ 17·58	90·78	37·12
28	335·10	188·533	3·05	34·66	17·86	91·16	37·05
30	335·61	189·388	3·50	34·69	18·14	91·55	36·97
Apr. 1	336·13	190·254	3·95	34·72	18·41	91·94	36·89
3	336·66	191·130	4·40	34·74	18·67	92·34	36·79
5	337·20	192·016	+ 4·85	+ 34·74	+ 18·93	92·74	36·68
7	337·76	192·912	5·31	34·74	19·19	93·14	36·56
9	338·32	193·817	5·77	34·73	19·44	93·55	36·44
11	338·89	194·731	6·23	34·72	19·69	93·96	36·30
13	339·47	195·655	6·69	34·70	19·93	94·37	36·16
15	340·06	196·587	+ 7·15	+ 34·67	+ 20·17	94·78	36·00
17	340·66	197·528	7·61	34·63	20·40	95·20	35·84
19	341·27	198·477	8·07	34·59	20·62	95·62	35·67
21	341·88	199·435	8·54	34·54	20·84	96·03	35·50
23	342·50	200·402	9·00	34·48	21·06	96·45	35·31
25	343·13	201·377	+ 9·46	+ 34·42	+ 21·27	96·87	35·12
27	343·77	202·361	9·92	34·35	21·48	97·29	34·92
29	344·42	203·353	10·38	34·27	21·68	97·70	34·72
May 1	345·07	204·354	10·84	34·19	21·88	98·11	34·51
3	345·73	205·363	11·29	34·10	22·07	98·52	34·30
5	346·40	206·381	+ 11·75	+ 34·00	+ 22·26	98·93	34·08
7	347·08	207·408	12·20	33·90	22·44	99·34	33·86
9	347·76	208·443	12·65	33·79	22·62	99·75	33·63
11	348·45	209·486	13·09	33·68	22·79	100·15	33·39
13	349·14	210·538	13·53	33·56	22·95	100·55	33·15
15	349·84	211·598	+ 13·97	+ 33·43	+ 23·11	100·94	32·90

Greenwich Noon.		Brightness.	Appar. Diam.	Defect of Illumination q	Equat.	Polar.	Central Meridian. ω_0	Passage of Zero Meridian.	
1897.		m	"	"	"	"	°	h m	h m
Mar.	8	0·73	7·96	·80	·62	·15	343·63	1 7	1 46
	10	0·77	7·83	·79	·62	·15	324·64	2 25	3 4
	12	0·81	7·70	·78	·61	·15	305·63	3 43	4 22
	14	0·85	7·58	·77	·60	·14	286·61	5 2	5 41
	16	0·88	7·47	0·76	0·59	0·14	267·58	6 20	6 59
	18	0·92	7·35	·75	·59	·14	248·54	7 38	8 17
	20	0·95	7·24	·74	·58	·13	229·48	8 56	9 35
	22	0·99	7·13	·73	·57	·13	210·42	10 15	10 54
	24	1·02	7·03	·71	·56	·13	191·34	11 33	12 12
	26	1·05	6·93	0·70	0·55	0·13	172·25	12 51	13 31
	28	1·08	6·83	·69	·54	·12	153·15	14 10	14 49
	30	1·11	6·74	·68	·54	·12	134·04	15 28	16 8
Apr.	1	1·14	6·65	·67	·53	·12	114·91	16 47	17 26
	3	1·17	6·56	·65	·52	·11	95·78	18 6	18 45
	5	1·20	6·47	0·64	0·51	0·11	76·64	19 24	20 4
	7	1·23	6·39	·63	·50	·11	57·49	20 43	21 23
	9	1·25	6·31	·62	·49	·10	38·33	22 2	22 41
	11	1·28	6·23	·60	·49	·10	19·16	23 21	...
	13	1·31	6·15	·59	·48	·10	359·98	0 0	0 39
	15	1·33	6·08	0·58	0·47	0·09	340·79	1 19	1 58
	17	1·36	6·00	·57	·46	·09	321·60	2 38	3 17
	19	1·38	5·93	·56	·45	·09	302·40	3 57	4 36
	21	1·40	5·87	·55	·45	·08	283·19	5 16	5 55
	23	1·43	5·80	·53	·44	·08	263·97	6 35	7 14
	25	1·45	5·74	0·52	0·43	0·08	244·74	7 54	8 33
	27	1·47	5·67	·51	·42	·07	225·50	9 13	9 52
	29	1·49	5·61	·50	·41	·07	206·25	10 32	11 11
May	1	1·51	5·56	·49	·41	·07	187·00	11 51	12 31
	3	1·53	5·50	·48	·40	·07	167·74	13 10	13 50
	5	1·55	5·44	0·47	0·39	0·06	148·47	14 29	15 9
	7	1·57	5·39	·46	·39	·06	129·19	15 48	16 28
	9	1·59	5·34	·45	·38	·06	110·90	17 8	17 48
	11	1·60	5·29	·44	·37	·06	90·61	18 27	19 7
	13	1·62	5·24	·43	·36	·05	71·31	19 47	20 26
	15	1·64	5·19	0·42	0·36	0·05	52·01	21 6	

In the preparation of the present ephemeris I have, not without hesitation, adopted the position of the axis of *Mars* which Hermann Struve has deduced from his investigation of the orbits of the satellites, published in No. 3302 of the *Astron. Nachrichten*. The inclination of the equator to the orbit of *Mars* is increased $0^\circ\cdot344$, but the node on the orbit set back $2^\circ\cdot973$, and it is a question whether the foundation for the new determination is already sufficiently secure to warrant its superseding the previous determination from spots. Nevertheless, I have considered it better to make the change, especially as the computed areographical positions of the Earth and Sun will serve for the satellites as well as for the planet.

P denotes the position-angle of the axis of *Mars*, $L-O+180^\circ$ the longitude of the Earth referred to the plane of *Mars'* equator, and reckoned from O, the point of the vernal equinox of the planet's northern hemisphere, B the latitude of the Earth, $\Lambda-L$ the difference of the longitudes of Sun and Earth, B the latitude of the Sun, Q the position angle of the greatest defect of illumination or $Q+180^\circ$ that of the Sun, E the areocentric angle between Earth and Sun.

The brightness of *Mars*, expressed in star magnitudes, is computed by Professor G. Müller's formula—

$$-1^{m}\cdot787+5\log\frac{r\Delta}{r_0(r_0-1)}+0\cdot01486a \text{ (here E)},$$

or rather by its equivalent—

$$+5\log(r\Delta)+0\cdot01486\,E+0\cdot703-2,$$

in which the defect of illumination is assumed to be represented by the empirical term containing the angle E expressed in degrees.

The measures of the planet's diameter made with powerful instruments and wire micrometers, demand the assumption of a larger value than that derived from measures made with heliometers of rather low power, but the most suitable assumption can only be made when the resulting measures of the equatorial and polar diameters for each observed set are published, so that the corrections for phase may be properly applied.

If a web or a line is moved in the direction of the position-angle p or $p+180^\circ$, the distance of the tangent to the curve forming the limit of illumination from the centre will be

$$a\sqrt{1-\sin^2 E\cos^2(p-Q)},$$

or the difference between the diameter $2a$ and the distance of the two tangents touching the visible disc will be

$$2a\left(1-\sqrt{1-\sin^2 E\cos^2(p-Q)}\right),$$

so that the defect of illumination is

$$2a\sin^2\tfrac{1}{2}\delta, \text{ if } \sin\delta=\sin E\cos p-Q.$$

For the equatorial and polar diameters the values of sin δ are accordingly sin E sin (P − Q) and sin E cos (P − Q) and for the diameters in position-angle 90° and 0° sin E sin Q and sin E cos Q, the visible defect being within 90° of Q.

The apparent diameters and the defects of illumination q in position-angle Q and of the equatorial and polar diameters are computed with the assumed value (at distance 1) 9″·60.

The difference of about 5°, which Mr. Percival Lowell has found between the areographical longitudes of some spots derived from his observations of 1894 and the corresponding longitudes of *Schiaparelli*, which the ephemeris was intended to represent approximately, requires to be traced to its source and to be cleared up. A search for some error in my computations, which might account for the difference, has hitherto been unsuccessful, and an alteration of the adopted rate of rotation, such as would reconcile the deduced longitudes of 1894 with those of 1879, could not be reconciled with the older observations. Under these circumstances I have had to defer the further search for the source of the error and to break the continuity of the "Longitudes of the Central Meridian" by adopting in the present ephemeris approximate alterations derived from Mr. Lowell's statements. When the detailed observations of 1896–97 as well as of 1894 shall have become known, I intend to resume the search.

The data of the ephemeris are already corrected for the equation of light, so that they are to be interpolated directly for the times for which they are required. The differences between successive values of ω_0, the longitude of the central meridian, vary between 700°·16 and 702°·45.

The ephemeris for the opposition of 1886 in vol. xlvi. of the *Monthly Notices* is accompanied on p. 33 by some remarks, which observers will perhaps bear in mind during the approaching observing season. "It is desirable that the question should be settled how far the variations in the aspect of the dark markings on *Mars* are due to the relative position of the Sun and the Earth, and especially what changes take place in the aspect of a marking, when, in the course of rotation, it reaches or leaves the vicinity of the point where Sun and Earth have the same zenith distances, but opposite azimuths." This point is in position-angle Q + 180 and at the areocentric angular distance $\frac{1}{2}$E from the apparent centre of the disc, but as "observers may perhaps be more readily induced to watch their opportunities, if they can easily get the areographical longitude ω' and latitude β' of the point," I gave there a special little list. As the present ephemeris contains the values of Λ − L and of *B* referring to the Sun, the areographical position of the point where the effect of reflected sunlight may be looked for is approximately—

$$\omega' - \omega_0 = -\tfrac{1}{2}(\Lambda - \mathrm{L})$$
$$\beta' = \tfrac{1}{2}(\mathrm{B} + B).$$

The seasons on *Mars* begin according to the assumed position of the planet's equator

1896 July 13·7 Winter solstice of *Mars*' northern hemisphere
Dec. 19·3 Spring equinox " " "

On April 8, at 1^h 32^m Gr. *Mars* passes $2'{\cdot}1$ south of the star $3^m{\cdot}2$ ϵ *Geminorum.*

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. MAY 8, 1896. No. 8

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

William Banks, 30 Corporation Street, Bolton, Lancashire ;
and
Alfred Ernest Young, Assoc. M. Inst. C.E., Trigonometrical Survey of Perak, Taiping, Perak, Straits Settlements,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Lewis Evans, J.P., F.S.A., Barnes Lodge, King's Langley, Herts (proposed by Sidney Waters) ;
John Anderton Greenwood, Solicitor, LL.M., B.A., Brooklyn, Earl's Court Square, S.W. (proposed by Capt. D. Forbes).

Seventy-six presents were announced as having been received since the last meeting, including, amongst others :—

W. T. Lynn, Remarkable Eclipses ; T. K. Mellor, A Handy Map of the Moon ; F. Tisserand, Traité de Mécanique céleste, tome iv., presented by the authors ; three photographs of Comet Rordame-Quénisset, presented by the Lick Observatory.

Some Notes on the Use and Adjustment of the Cœlostat. By H. H. Turner, M.A., B.Sc., Savilian Professor.

The name "cœlostat" was suggested by Mons. G. Lippmann (*C.R.* cxx. No. 19) for that form of heliostat in which the mirror rotates round an axis in its plane, and parallel to the Earth's axis, once in two days. A telescope fixed to the Earth and pointed to such a mirror will always see the same stars, as though they were attached rigidly to the Earth. The instrument seems specially suitable for eclipse work, and three such will be sent out in the forthcoming eclipse expeditions to Japan and Norway, organised by the Joint Permanent Eclipse Committee of the Royal and Royal Astronomical Societies. One of these has been tried at Oxford during the last few months, and the following notes on its adjustments &c. may be found useful by others working with the instrument.

Support for Cœlostat.

This should be as firm as possible—stone or brick, with concrete foundation, if there is time and opportunity. No precautions to ensure steadiness are to be looked upon as unnecessary. It is a great comfort to feel that the adjustments, once made, are permanent. But, in case nothing better is available, a very good support can be made of the wooden box for the instrument, (especially if it be filled with sand, or sand and stones), placed on the soil. A cœlostat was mounted on its box, without any filling of sand, at Oxford; the box resting on two planks scraped into the ground and levelled. The adjustments had only altered by a few minutes of arc in a fortnight, probably through the yielding of the wood at the points of greatest pressure from the weight of the instrument.

When placed on the box, the height of the centre of the mirror is 3 feet 6 inches, and the instrument is suited for work with a horizontal telescope. But if the telescope is to point downwards, as will probably be found most convenient in general (see below "*Position of Telescope*"), the box will be unnecessary, and a flat stone or a flat board will be all that is required. Perhaps the iron base might rest on the bare earth if sufficiently firm.

Support for Telescope.

No means of securing steadiness are thrown away, but even rougher methods may do here. No permanence of adjustment is required—just the contrary, for the telescope must be shifted to follow the Sun in declination. But when once pointed on the Sun, there should be some method of clamping it tightly, so that the putting in and out of the plate and the opening of the exposing shutter, &c., may not shake it. But it will readily be seen that even the flimsiest method of holding the telescope in this way is superior to that of the ordinary equatorial.

For the telescope in the horizontal position, the following method was adopted at Oxford with good results. Two parallel horizontal bars were screwed to posts driven into the ground, forming virtually a horizontal table. The telescope (a wooden tube of rectangular section) could be shifted about on these bars at will, and when properly pointed two or three spare clock weights placed on the top of it, and one or two very thin wooden wedges pushed under the tube with the fingers made a very steady mounting.

If the telescope is not to be horizontal, one bar must be higher than the other, and the slipping of the tube lengthways may be prevented by wooden fillets on the tube, which should come against the bars. Instead of the weights, which might slip down the tube unless similarly held by fillets, a rope might be bound once or twice round the tube and firmly attached to the bars.

Huts and Coverings.

In the early experiments at Oxford I started with the idea of keeping the telescope in the hut and putting the cœlostat outside. I think this is wrong. The cœlostat ought to be indoors and the telescope outside, for several reasons.

(*a*) If a hut is built over the telescope it is very difficult to avoid cutting off some of the sky, especially if any attempt is made to cover the cœlostat also. I need not here reproduce the details of suggested plans, of which several were considered. Those who come to work with the instrument will quickly realise the difficulties.

(*b*) The telescope can easily be lifted indoors. No permanent adjustment is required, as above remarked, and the supports can be left outside in the weather.

(*c*) It is, of course, more comfortable for the observer to be indoors if possible, especially at night in cold weather. But on the occasion of an eclipse considerations of this kind are not much to the fore; and there are other reasons why he would prefer to be in the open.

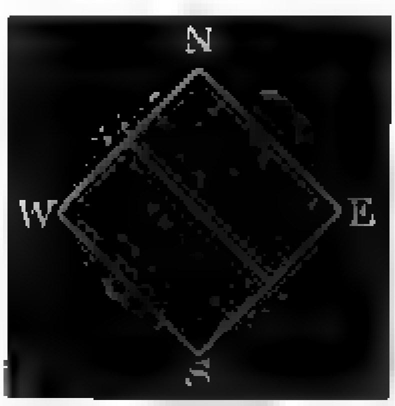
(*d*) On the other hand, the cœlostat ought to be indoors. The metal work is liable to rust with exposure to weather—even under a tarpaulin, say—and the mirror will dew if it is not warmer than the outside air. By placing cœlostat and clock in a hut, where, if necessary, an oil stove can be lighted to warm the place, the dangers of rust and dew are greatly diminished. It ought to be made *quite certain* that the mirror is warmer than the outer air before opening the hut to observe the eclipse : for, if the mirror dews over, there may not be time to get the surface clear again before totality commences.

(*e*) If the cœlostat is indoors it can be cleaned or adjusted in various ways, clock rated, &c., during inclement weather, when it could not otherwise be uncovered.

For these and other reasons I propose to put the cœlostat in the hut, which the observer will in any case require for storing boxes, books, and instruments, and which may be used also as a dark room, and even as a sleeping apartment. The cœlostat should be at the south side or corner of the hut, so that when a southern window or door is opened a good view of the zodiac is obtained.

As regards the particular form of the hut much may be left to be settled for the particular place, occasion, or observer; but as there are many advantages in uniformity, it may not be amiss to suggest a simple plan as a "working hypothesis," for subsequent modification.

If the hut is to be made on the spot one great desideratum is simplicity. Let us start with the simplest form of hut, viz. the five faces of a cube, the ground forming the sixth. The side of the cube may be taken as 10 feet. The roof, however, should be pent-house, not flat; and we may perhaps reduce the height from 10 feet to 8 feet at the cross-bar, and 6 at the sides. There should be at least one door and one window; and we may make use of these to admit light to the cœlostat. Place the hut with its *corners* N., E., S., W., and the cœlostat at the S. corner. Then a door in the S.E. face, extend-



ing from the S. corner to the middle of the face, would admit the Sun in the morning, and a door in the S.W. face would similarly admit it in the afternoon. The doors would be rather wide (5 feet), but this would not matter. They should be hinged on posts in the middle of the faces (one of which would be necessary to support the cross-bar of the roof), and they would then close against the post at the S. corner. This post would be practically the only obstacle to a clear view for the cœlostat; for the roof would only cut off the sky near the zenith, which is not wanted for eclipse work.

Windows may be added according to taste and fancy, or may be dispensed with altogether in favour of an open door, for it would be rather cruel weather if one of the two doors could not be opened without admitting the rain. Half of the hut may be partitioned off as a dark room, if thought desirable, by a partition

along the roof cross-bar, and the part of the hut north of the cross-bar may be extended at pleasure to give sleeping room &c.

It will be noticed that there is a post on the meridian of the cœlostat, and this might be thought a disadvantage. It might obscure the view of the adjusting theodolite just on the meridian, and if we were taking transits this would be a drawback; but as for adjusting an equatorial we only want a view *near* the meridian no harm is done, and if we use the image of the Sun in the telescope itself, by reflection from the mirror (see below) to adjust by, even the meridian need not be cut off seriously. If the actual meridian view is important the cœlostat may be placed slightly to one side of the post, or finally, it is not difficult to dispense with this post altogether.

Position of the Telescope.

This may be considered from two points of view:—

(1) *Generally* without reference to the latitude of the place or time of day.

(2) *Locally*, *i.e.* with reference to the altitude and azimuth.

Let us first take the general considerations, viz. *inclination* of telescope to mirror, and *distance* from mirror.

The *inclination* of direct or reflected ray to mirror is a minimum when the star or sun is in the same hour circle as the telescope. This hour circle is of some importance and is frequently to be referred to, and it will be convenient to have a short designation for it. I cannot think of any which quite satisfies me, but perhaps the letters T.H.C. (telescope-hour-circle) would do. They will be used in this paper to denote the great

circle through the poles and the telescope. Thus if P be the Pole, S the star, N the normal to the mirror, and S′ the image of the star, PS′ is the T.H.C., and we have the relations

$$PN = 90^\circ$$
$$NS = NS' = i$$
$$\angle NPS = \angle NPS' = \tfrac{1}{2}h$$
$$PS = 180^\circ - PS' = p = 90^\circ - \delta.$$

where p is the N.P.D., or δ the declination, of the star, h its hour angle *reckoned from the* T.H.C., and i the inclination of either direct or reflected ray to the mirror-normal.

Further

$$\cos i = \sin p \cos \tfrac{1}{2}h = \cos \delta \cos \tfrac{1}{2}h.$$

The following small table shows the way in which i changes with h for different declinations in and near the zodiac.

Star's Hour angle from T.H.C.

Decl.	h 0·0	h 0·5	h 1·0	h 1·5	h 2·0	h 3·0	h 4·0	h 5·0
° 0	° 0·0	° 3·8	° 7·5	° 11·3	° 15·0	° 22·5	° 30·0	° 37·5
10	10·0	10·6	12·4	15·0	18·0	24·5	31·5	38·6
20	20·0	20·3	21·3	22·8	24·8	29·7	35·5	41·8
30	30·0	30·2	30·8	31·9	33·2	36·9	41·6	46·6

The inclination of incident to reflected ray will be double this in all cases, but this double angle does not much concern us.

Owing to this inclination of the rays, the circular mirror will yield an available cylinder of rays *elliptic* in section. The major axis of the ellipse is always equal in length to d, the diameter of the mirror; but its direction depends on h, the hour-angle from T.H.C. The minor axis is of length $d \cos i$. We can generally keep i less than 24° for eclipse work; and thus the minor axis for a 16-inch mirror is not less than $14\frac{1}{2}$ inches. But it may be important to take account even of this small diminution. When $h=0$ the major axis of the ellipse is perpendicular to the polar axis for objects of all declinations, but it rotates as h changes. If the telescope is not circular in section (*e.g.* if it is a combination of two telescopes) it may be advisable to arrange that the long axis of the telescope section corresponds in direction to the major axis of the ellipse, which is always perpendicular to NS′. The angle NS′P represents the amount of rotation of the major axis from its position when the star is on the T.H.C. If we put a for this angle we have

$$\tan a = \tan \tfrac{1}{2}h \sec p.$$

Thus a can be readily calculated. For declination 16°, as in the eclipse of 1896 August 9, we have the following values for a at different hour angles from T.H.C.:—

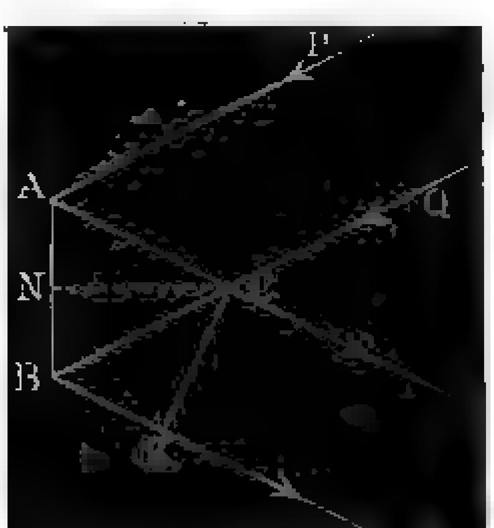
h	a	h	a
h 0·0	° 0	h 1·5	° 36
0·5	13	2·0	45
1·0	25	2·5	51

On the occasion of an eclipse it will generally be possible to arrange that the Sun should not be far from the T.H.C. (unless the Sun be very near the equator), and then the major axis of the ellipse is nearly perpendicular to the polar axis of the Earth or cœlostat. If, however, the Sun is on the equator, we cannot observe it in the T.H.C., for the telescope will get in the way; and then the major axis will be more nearly *parallel* to the polar axis.

As regards the *distance* of the object glass or glasses from the mirror: this must not be too great since the field of view is of finite angular dimensions; nor again too small, or the telescope will be in the way of the incident light.

The former limit depends on the diameter of the field to be photographed. For the Abney lenses, in general use for recent eclipses, a plate 6 inches square is used at the focal length of $5\frac{1}{4}$ feet. The angular distance of a side from the centre is thus nearly 3°, and of a corner more than 4°. Thus the cylindrical projection of the object glass must have a margin of 3° or 4°. For the other lens mounted alongside in the double tube the angular radius of the field is not so great, owing to the enlargement of the image; but we want a radius of 2° if possible. [It may be here remarked that although detail of the corona is not visible to the eye near the edges of the plates, the density of deposit has been measured on these plates right up to the edge, and found to have by no means reached uniformity, and for some reasons even larger plates would be better.] Hence we want an outside margin of 5° or 6° on the mirror to be safe. At a distance of the object glasses from mirror of 3 feet this would mean $3\frac{1}{2}$ inches to be added to the distance between the outside edges of the lenses, which is 10 inches. Hence we should not go much further away than 3 feet to be safe.

As regards the inferior limit of distance, if A B be the mirror, P A, Q C the incident, and A C, B K the reflected rays,



it is clear that the front of the telescope should not come nearer than the position C K (for parallel rays and a tube filling the

whole section C K). The distance C N is $\frac{1}{2}$ AB cotan. inclination or for a 16-inch mirror, C N is as follows for different inclinations :—

i	CN	i	CN
5°	91 inches	25°	17 inches
10	46 "	30	14 "
15	30 "	35	11 "
20	22 "	40	10 "

Since the tube is smaller than the mirror the above limits are tolerably safe ones; but the angular radius of the field should be added to the inclination for the central ray in taking C N from this table. For the present eclipse, where $i=16°+$ field$=20°$ say, the distance 3 feet seems quite safe even when the Sun is on the T.H.C.

Local considerations.—The azimuth of the telescope will not much matter, only its inclination to the horizon.

(*a*) There are some conveniences in having the telescope horizontal, and then it must be placed in either the rising or setting points of the Sun's image in the mirror. The inclination of the rays to the mirror may, however, be too large for convenience in this position. This inclination can be seen at a glance from the table on p. 412, entering the table with the Sun's declination on the left, and at the top the difference between the time of totality and the time of rising (or setting) of the Sun's image. Thus for Vadso the *Sun's image* (*i.e.* body of equal and opposite declination to Sun) rises at $20^h \cdot 5$, and the time of totality is 18^h, the difference being $2^h \cdot 5$: and the Sun's declination is 16°. Hence the inclination i is about 24° if the telescope be horizontal. For Kushiro the time of totality is $3^h \cdot 3$, and the Sun's image sets at $5^h \cdot 0$, the difference being $1^h \cdot 7$. Hence $i=19°$ for the horizontal position.

(*b*) The meridian may often be a good place for the telescope. A side shift then does not affect the position of the image in declination, and this may be a convenient arrangement. The orientation of the image is also conveniently disposed.

(*c*) But unless the Sun's declination is very small it may be best to arrange so that the Sun at totality is in the T.H.C. It will be inclined to the horizon, but this is a positive convenience when the inclination is not too great. The plate-holders remain in position by gravity alone, without spring supports. The cœlostat can be on the ground and yet the observer work at a convenient height.

(*d*) Intermediate positions may be selected to combine any of these advantages. It does not very much matter indeed where the telescope is so long as totality does not occur too far from the T.H.C.

ADJUSTMENTS.

Adjustment of rate of clock.—This is put first because it should be independent of the place, and should be settled before starting on the expedition. The number of revolutions which the governor (or of some part of the clock of which the revolutions can be counted) should make in a minute can be determined, either by counting the number of teeth in the driving sector and different wheels of the train, or by direct observation of Sun or stars; and thus the clock can be regulated with a good watch indoors on a wet day if necessary. If possible, the driving-clock should be arranged to strike every minute, which would save tedious counting.

Adjustment of altitude and azimuth.—A declination theodolite is provided which can be attached to the axis of the mirror, and thus the axis can be adjusted in altitude and azimuth like an equatorial in the ordinary way by observing a star east and west on the meridian. A level is attached to the telescope, so that if the latitude be known the adjustment in altitude can be made very simply by setting the telescope to a south declination equal to the colatitude, and screwing up the instrument until the level bubble shows the telescope to be horizontal. A single observation of the Sun east or west will then suffice for the azimuth adjustment; or if the local time be known, and a cross level be provided for the pivots of the telescope, a transit observation of any object on the meridian will adjust in azimuth. As regards the accuracy of adjustment necessary, Dr. Schuster concludes (*Phil. Trans.* vol. clxxx. 1889, A, pp. 291–350) that an error of 3′ or 4′ is allowable in the position of the instrumental pole; for the Sun's motion in declination may be so large as to correspond to a maladjustment of this magnitude; while the error to be feared from indifferent clock-driving is greater. But assuming that the clock can be got to go well, the effect of the Sun's motion in declination may be allowed for by deliberately putting the instrumental pole slightly out of adjustment. The rule for the displacement may be readily deduced as follows:—

The Sun has practically two angular rotations, one round P, the Earth's pole, in one day; the other round E, the ecliptic pole, in $365\frac{1}{4}$ days and in the reverse direction. The resultant is a rotation round the pole Q in EP produced, where

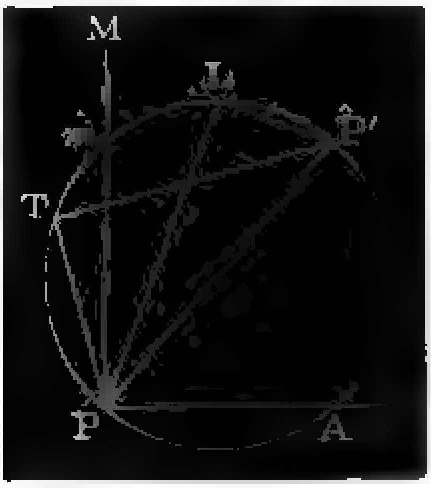
$$PQ = EQ/365\tfrac{1}{4} = 24^\circ/360 \text{ (say) } = 4'.$$

The point Q revolves round P during the day, and hence we can only compensate the Sun's annual motion for one time of the day if the instrument is to remain undisturbed; but it will clearly be convenient to choose for this time the time of totality. The rule will then be: Adjust the instrument to the true pole, and then disturb its pole 4′ in the direction opposite to

that in which the ecliptic pole lies at the hour of totality. The clock must of course keep *solar* time.

The final adjustments may perhaps be best made photographically. Pointing a telescope to the mirror, and letting the clock drive, take two photographs of the Sun at intervals of ten minutes, or even half an hour. The motion in declination can be measured on the photograph. Repeat the operation at another hour-angle. Then we have sufficient to give us completely the exact position of the instrumental pole.

If γ be the displacement of the instrumental pole from the true, K its hour-angle, then the declination of an object in hour-angle T will read apparently too great by $\gamma \cos (T-K)$. If we watch the *motion in declination* for one minute this will be a



decrease of $\cdot 0044\, \gamma \sin (T-K)$. A graphical construction will generally be sufficiently accurate for determining the displacement of the instrumental pole by either method. Consider, for instance, the first. Suppose we have observed the errors in declination at two hour-angles $-h_1$ and h_2 to be e_1 and e_2. Let P represent the pole and PM the meridian, and draw PT of length e_1 in the direction of the first hour-angle (*i.e.* $\angle \mathrm{TPM}=h_1$); PL of length e_2 in that of the second. Draw perpendiculars TP′, LP′ to PT and PL, meeting in P′, and on PP′ as diameter describe the circle PTLP′. Then P′ is the instrumental pole; and hence

$$\mathrm{PP'}=\gamma \text{ and } \angle \mathrm{MPP'}=\mathrm{K}.$$

For

$$\mathrm{PT}=\mathrm{PP'} \cos \mathrm{TPP'}=\gamma \cos(-h_1-\mathrm{K})$$
$$\mathrm{PL}=\mathrm{PP'} \cos \mathrm{LPP'}=\gamma \cos(h_2-\mathrm{K})$$

The total displacement PP′ is compounded of a displacement P*m* in altitude and PA × cosecant latitude in azimuth. The error in declination at any other hour-angle is found by drawing a line from P to the circumference of the circle.

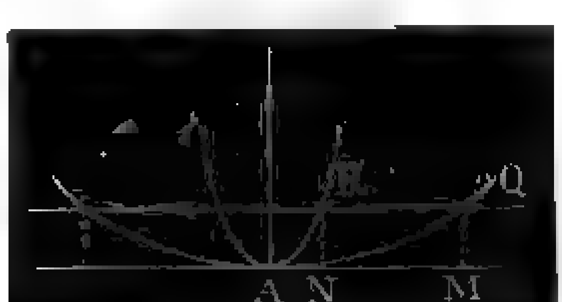
The modification of this construction for the *motion in declination* is tolerably obvious.

Adjustment of Mirror.

Only one adjustment concerns us—the parallelism of the face of the mirror to the axis of rotation. The instrument-maker may be trusted to get this nearly right; and since the mirror can be reversed in its pivots, we can soon detect any great want of parallelism by observing any terrestrial or celestial object by reflection from the mirror in a fixed telescope, and then reversing the mirror in its pivots. But it is not easy to get this adjustment quite exact. The mirror is held in its cell by three brass lugs, which are screwed up into a groove running round the edge; and the position it takes up is subject to slight alterations. For instance, the parallelism of the mirror was tested on March 31 at Oxford as follows:—

The Sun was swept into the telescope (by reflection from the mirror) and its image viewed on the ground glass. A piece of gummed paper was stuck on the glass and the path of the Sun marked on the paper with a pencil. The mirror was then reversed, and the Sun was found to travel about 20′ north of the previous mark. One of the three screws used to lower the mirror into its cell was then inserted into its socket and screwed into very gentle contact with the back of the mirror. The error was found to be over-corrected. The screw was then removed, but the mirror did not fall back, and the error remained over-corrected even after reversal. The arrangements for this adjustment need further investigation.

The *effect* of any want of adjustment is that the image of a star, instead of remaining stationary, would describe a small ellipse on the plate about its mean position, the axes of the ellipse being 4ψ and $4\psi \sin \delta$, where ψ is the tilt of the mirror to the polar axis, and δ the declination of the star, the minor axis of the ellipse being perpendicular to the polar axis (see Appendix). But



only the small portion of this ellipse corresponding to practicable positions of the mirror would be actually described, viz. that near one of the ends of the major axis. If A be such an apse, then, when the star and its image are in the same hour-circle, the image falls at A; but with lapse of time the image travels along a curve, AR or AQ, according to the declination of the star. The travelling along ANM goes into the clock-rate, and

it would make the clock-rate apparently different for objects of different declination.

The travelling perpendicular to AM is the same for all declinations. It is distinguished from such travelling, due to maladjustment of the polar axis, by being zero on the T.H.C., wherever this may be, and for all stars.

The following table gives the distance RN or QM for different times (but for all stars, whatever their declination) for a tilt of 10′ in the mirror :—

m	″	m	″
40	0·5	160	7·2
80	1·8	200	11·3
120	4·1	240	16·1

It thus appears that there is an advantage in using the mirror near the T.H.C. ; for the rate of change in this coordinate is only 0″·5 for the first half-hour, but ten times this amount four hours away.

It is clear, however, that for work on the Sun near the T.H.C. the motion arising from tilt is small, and if the adjustment is tolerably good may be neglected.

Some Useful Formulæ.

In the paper above cited Dr. Schuster gives "some formulæ which may be useful to future eclipse observers." As these notes may be in the hands of those who may not have Dr. Schuster's paper with them I reproduce the formulæ here. I would remark, however, that I think Dr. Schuster's fundamental supposition about resolving power (see p. 298 of his paper, *Phil. Trans.*, 1889 A), scarcely applicable to photographic resolving power. It is too small ; but a discussion of this point would be out of place here.

ϕ is the displacement in seconds of arc which is allowable, consistent with full definition.

R is the true aperture of the lens in centimetres.

R′ is the effective aperture of the lens in centimetres.

q is the time of exposure in seconds.

Q is the longest time of exposure compatible with full definition.

γ is the greatest allowable angle between the true pole and the pole of the instrument in seconds of arc.

T is the change of solar declination measured in seconds of arc per second of time.

e is the error of the clock-rate measured in per cent.

In equations (2) (4) (6) it is assumed that in adjusting the pole of the equatorial no account is taken of the change of the solar declination during the eclipse.

$$\phi = 2 \cdot 5/R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$Q = 2 \cdot 5/RT \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\gamma = 34600/Rq \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Or if the longest exposure Q is to be used

$$\gamma = 13840\ T \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Finally to determine R′, we easily find

$$\frac{1}{R'} - \frac{1}{R} = 60 \times 10^{-} \times qe \quad . \quad . \quad . \quad . \quad . \quad (5)$$

This equation will allow us to determine the time of exposure allowable for a given effective aperture R′ if the clock-rate is known. If the longest exposure Q is to be used, we get

$$\frac{R - R'}{R'} = \frac{1 \cdot 5 \times 10^{-9} \times e}{T} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

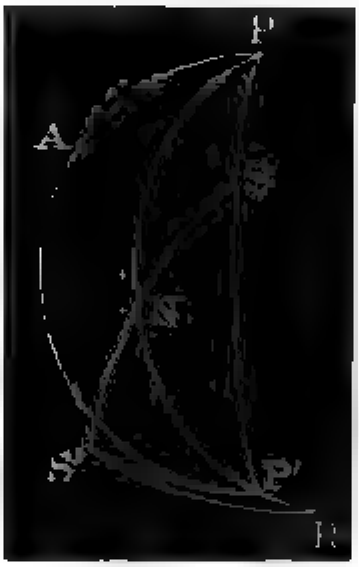
Appendix on the form of the closed curve on the sphere described by the reflected ray when the mirror is inclined to the polar axis.

Let P be the North Pole, P′ the South Pole, S a star, and S′ its image. N the normal to the mirror. When the adjustment is perfect, N bisects PNP′ and also SNS′, and the triangles SNP, S′NP′ are equal in all respects. The meridian PAS′P′ is

fixed, and S′ is a fixed point on it (since P′S′=PS=constant), and the meridian PNP′ containing the point N travels at half the rate of the meridian PSP′ containing the point S.

But suppose the mirror tilted at an angle ψ to the polar

axis so that PN is no longer $\frac{\pi}{2}$ but $\frac{\pi}{2}+\psi$. Then S′ no longer falls on PAP′ but we still have SN=NS′.



Also if the clock rate is properly adjusted

$$\angle SPN = \angle APN = \phi \text{ say}.$$

Now take in PN produced, NR=NP.

Then since

$$NR, NS' = NP, NS$$

and

$$\angle S'NR = \angle SNP,$$

the triangles S′NR, SNP are equal in all respects, so that

$$RS' = PS \text{ and } \angle S'RN = \angle NPS = \phi = \angle AP'N.$$

Further,

$$P'R = 2\psi.$$

The locus of S is thus defined most simply by reference to the point P′, as follows :

R is any point on a small circle centre P′ and radius

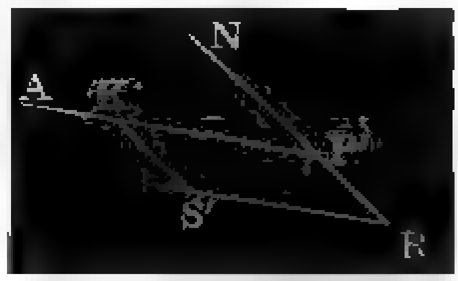
$$P'R = 2\psi.$$

From R is drawn RS′ of constant length RS′=p the N.P.D. of the star, and making with RP′ the same angle as the fixed meridian AP′ makes with RP′; *i.e.*

$$\angle APN = \angle S'RP'.$$

If the surface were a plane instead of a sphere, the locus would be a circle. For if in plane geometry

$$\angle AP'N = \angle S'RP'$$



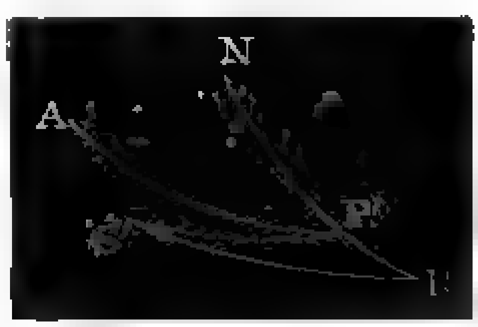
RS' will be parallel to PA. And since RS' is constant in length, if we take

$$P'K = RS',$$

then KS'RP' is a parallelogram and

$$KS' = P'R,$$

and is constant in length. Thus S' describes a circle about K.



But in spherical geometry the locus of S' is more complicated. We have

$$\begin{aligned}
\sin P'S' \sin S'P'N &= \sin S'R \sin S'RP' \\
&= \sin p \sin \phi \\
\sin P'R \sin P'S' \cos S'P'N &= \cos P'R \cos P'S' - \cos S'R \\
&= \cos P'R(\cos P'R \cos S'R + \sin P'R \sin S'R \cos S'RP') - \cos S'R \\
&= -\cos S'R \sin^2 P'R + \cos P'R \sin P'R \sin S'R \cos S'RP'
\end{aligned}$$

Thus

$$\sin P'S' \cos S'P'N = -\cos p \sin 2\psi + \cos 2\psi \sin p \cos \phi.$$

Hence

$$\begin{aligned}
\sin P'S' \sin S'P'A &= \sin P'S' \sin (S'P'N - \phi) \\
&= \sin p \sin \phi \cos \phi - \sin \phi \,[\cos 2\psi \sin p \cos \phi - \cos p \sin 2\psi] \\
&= \sin \phi \,[\cos p \sin 2\psi + 2 \cos \phi \sin p \sin^2 \psi] \\
\sin P'S' \cos S'P'A &= \cos \phi \,[\cos 2\psi \sin p \cos \phi - \cos p \sin 2\psi] + \sin p \sin^2 \phi \\
&= \sin p - \cos \phi \,[\cos p \sin 2\psi + 2 \cos \phi \sin p \sin^2 \psi].
\end{aligned}$$

Now let

$$x' = \sin \mathrm{P'S'} \cos \mathrm{S'P'A},\ y = \sin \mathrm{P'S'} \sin \mathrm{S'P'A},$$

so that (x', y) are the rectangular coordinates of the orthogonal projection of S′ on the tangent plane at P′. Further let

$$x = \sin p - x';$$

so that (x, y) are rectangular coordinates on this plane referred to a new origin. Then if we put $x = r \cos \theta$, $y = r \sin \theta$, we have

$$r^2 = x^2 + y^2 = [\cos p \sin 2\psi + 2 \cos \phi,\ \sin p \sin^2 \psi]^2$$

and

$$\tan \theta = \frac{y}{x} = \tan \phi:$$

thus

$$\cos \phi = \pm \cos \theta.$$

Thus the equation to locus of (x, y) is in polar coordinates

$$r = a + b \cos \theta$$

where

$$a = \cos p \sin 2\psi,\ b = 2 \sin p,\ \sin^2 \psi.$$

This is the equation to a limaçon; and the locus of S′ is thus the orthogonal projection of a limaçon (drawn on the tangent plane at the South Pole) on to the sphere. The pole of the limaçon is at the point $x' = \sin p$, i.e. the projection of the point when the image would fall with perfect adjustment.

The shape of the limaçon depends on the ratio b/a. When this is zero or infinite the curve is a circle; when it is unity, a cardioid. This ratio is $\tan p \tan \psi$; and if ψ is small but finite, the cases of a circle are $p = 0$ and $\frac{\pi}{2}$; *i.e.* the images of a star exactly at the Pole or exactly at the equator. In the former case $(p = 0)$; we have $r = \sin 2\psi$ in the latter $\left(p = \frac{\pi}{2}\right)$ we have $r = 2 \sin^2 \psi \cos \theta$, the dimensions of the curve depending on the *square* of ψ and being thus of the second order. For a cardioid we have

$$p = \frac{\pi}{2} \pm \psi,$$

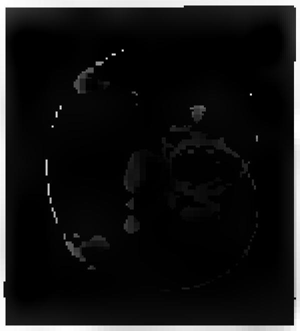
which indicates objects very near the equator.

Generally the maximum and minimum values of r are

$$a \pm b; \text{ or } 2 \sin \psi \cos (p \pm \psi).$$

r is always positive if $p \pm \psi$ never exceeds $\frac{\pi}{2}$; but if this condition

is not fulfilled (*i.e.* for objects close to the equator) the cusp of the cardioid becomes a double point, and there are two loops to



the curve. But the dimensions of the curve are then very small, depending on ψ^2.

Generally the curve will be a closed oval though the curvature is reversed for a small portion of the curve. But since b depends on ψ^2 and a on ψ, the curve will not be very different from a circle, radius $\cos p \sin^2 \psi$.

But we must remember that the limaçon itself is only the projection of the curve on the sphere with which we are really concerned; and for eclipse work we are dealing with the zodiac, and the projection is thus at a considerable angle. The tangent plane to the sphere in the neighbourhood of the image is inclined at an angle p to that on which the limaçon is drawn. Hence the dimensions parallel to axis of x are lengthened in the ratio $\sec p$; those parallel to y remaining nearly the same. Thus the curve will be something like an ellipse, the lengths of the axes being $2 \sin 2\psi$ and $2 \cos p \sin 2\psi$ respectively. This is the result quoted in the text.

Note on the Solution by Least Squares of the Equations arising in the Reduction of Photographic Star-plates. By Harold Jacoby.

In the determination of the constants of a photographic plate from the measured coordinates of known stars on the plate, we have to carry out the solution of a set of linear equations by the method of least squares or otherwise. The coefficients in these equations possess a peculiarity which will enable us to effect a rigorous least square solution with very little labour. If we indicate by p and r the scale value and orientation constants, and by k and c the two errors of centring, we shall have from the right ascensions of the known stars a series of equations of the form

$$ap + br + k + d' = 0.$$
$$\vdots \qquad \vdots$$

From the declinations we get another series of equations as follows :—

$$bp - ar + c + d = 0.$$
$$\vdots \qquad \vdots$$

If the number of stars be n, and if we indicate the summation of n quantities in the usual way by means of square brackets, the rigorous least square solution of the above $2n$ equations is given by the following formulæ :—

$$A = [aa] - \frac{[a]^2}{n},$$

$$C = [ad'] - \frac{[a]\,[d']}{n},$$

$$D = [bb] - \frac{[b]^2}{n},$$

$$E = [bd'] - \frac{[b]\,[d']}{n},$$

$$C' = [bd] - \frac{[b]\,[d]}{n},$$

$$E' = -[ad] + \frac{[a]\,[d]}{n},$$

$$p = -\frac{C + C'}{A + D}, \qquad \text{weight of } p = A + D,$$

$$r = -\frac{E + E'}{A + D}, \qquad \text{weight of } r = A + D,$$

$$k = -\frac{1}{n}\Big\{[a]\,p + [b]\,r + [d']\Big\}, \text{ weight of } k = n - \frac{[a]^2 + [b]^2}{[aa] + [bb]},$$

$$c = -\frac{1}{n}\Big\{[b]\,p - [a]\,r + [d]\Big\}, \text{ weight of } c = n - \frac{[a]^2 + [b]^2}{[aa] + [bb]}.$$

With the help of a Thomas or Brunsviga calculating machine, these formulæ enable us to perform a least square solution in a very short time indeed. As an example, let us take the following set of equations, which occurred in the discussion of a plate taken by M. Henry at Paris, 1891 December 2.

Equations derived from the Right Ascensions.

a $\quad b \quad\quad d'$	*Res'l.*
$-37p+15r+k+3''{\cdot}03=0$	$+0''{\cdot}94$
$-33p-\ \ 2r+k+2{\cdot}69=0$	$+0{\cdot}31$
$-24p+13r+k+1{\cdot}56=0$	$-0{\cdot}68$
$-19p+11r+k+1{\cdot}63=0$	$-0{\cdot}68$
$-16p+16r+k+2{\cdot}51=0$	$+0{\cdot}24$
$-\ \ \cdot p-\ \ 3r+k+1{\cdot}93=0$	$-0{\cdot}74$
$+\ \ 2p-27r+k+4{\cdot}16=0$	$+1{\cdot}11$
$+\ \ 2p-\ \ 1r+k+1{\cdot}97=0$	$-0{\cdot}70$
$+24p\quad 0r+k+1{\cdot}88=0$	$-0{\cdot}97$
$+32p+33r+k+3{\cdot}16=0$	$+0{\cdot}72$
$+34p+17r+k+3{\cdot}16=0$	$+0{\cdot}46$

Equations derived from the Declinations.

b $\quad -a \quad\quad d$	*Res'l.*
$+15p+37r+c-15''{\cdot}15=0$	$-0''{\cdot}51$
$-\ \ 2p+33r+c-14{\cdot}56=0$	$+0{\cdot}18$
$+13p+24r+c-15{\cdot}44=0$	$-0{\cdot}97$
$+11p+19r+c-13{\cdot}08=0$	$+1{\cdot}34$
$+16p+16r+c-14{\cdot}62=0$	$-0{\cdot}29$
$-\ \ 3p+\ \ \ r+c-13{\cdot}41=0$	$+0{\cdot}87$
$-27p-\ \ 2r+c-14{\cdot}77=0$	$-0{\cdot}32$
$-\ \ \ p-\ \ 2r+c-14{\cdot}09=0$	$+0{\cdot}13$
$0p-24r+c-14{\cdot}46=0$	$-0{\cdot}57$
$+33p-32r+c-13{\cdot}19=0$	$+0{\cdot}29$
$+17p-34r+c-13{\cdot}73=0$	$-0{\cdot}13$

We have here—

$$n=11,$$

$[a]=-36,\quad [b]=+72,\quad [d']=+27{\cdot}68,\quad [d]=-156{\cdot}50$

$[aa]=+6416,\quad [ad']=-\ 45{\cdot}44,\quad [bb]=+2892,\quad [bd']=+156{\cdot}36$

$[bd]=-992{\cdot}22,\quad [ad]=+613{\cdot}78.$

Consequently—

$A=+6298{\cdot}18,\quad C=+45{\cdot}15,\quad D=+2420{\cdot}73,\quad E=-\ 24{\cdot}82,$

$C'=+32{\cdot}14,\quad E'=-101{\cdot}61,$

And therefore—

$$
\begin{aligned}
p &= -\ {\cdot}0089, &&\text{weight } 8719.\\
r &= +\ {\cdot}0145, &&\quad ,, \quad 8719.\\
k &= -\ 2''{\cdot}64, &&\quad ,, \quad 10{\cdot}3\\
c &= +\ 14{\cdot}24, &&\quad ,, \quad 10{\cdot}3.
\end{aligned}
$$

If we substitute these values of the unknowns in the original equations, we get the series of residuals given above. The sum of the squares of the 22 residuals is 10·3179, so that we have—

$$
\begin{aligned}
&\text{Mean error of one equation} &&= \pm\,0''{\cdot}76,\\
&\text{Mean error of } p \text{ or } r &&= \pm\,0{\cdot}0081.\\
&\text{Mean error of } k \text{ or } c &&= \pm\,0{\cdot}24.
\end{aligned}
$$

The above method of computation is so simple, and requires so little time, that there seems to be no reason to substitute some other method for the method of least squares in the reduction of photographic plates. It should be noted, however, that in the foregoing computations all the equations received unit weight. But it might be desirable to give different weights to the equations derived from the declinations and right ascensions. In that case some of the simplicity of the solution here given is lost. But we can still employ a tolerably simple system of formulæ. If we compute, in addition to the auxiliaries already computed, the quantity—

$$\mathrm{B} = [ab] - \frac{[a]\,[b]}{n},$$

and if we assume that the right ascension equations are to receive the weight w, and the declination equations the weight w', we can obtain the values of the unknown quantities, such as they result from a rigorous least square solution, by the following system of formulæ :—

$$
\begin{aligned}
&\mu_1 = w\mathrm{A} + w'\mathrm{D},\\
&\mu_2 = (w - w')\mathrm{B},\\
&\mu_3 = w\mathrm{C} + w'\mathrm{C}',\\
&\mu_4 = w\mathrm{D} + w'\mathrm{A},\\
&\mu_5 = w\mathrm{E} + w'\mathrm{E}',\\
&\mathrm{Q}_1 = \mu_4 - \frac{\mu_2^2}{\mu_1}, \qquad \mathrm{Q}_1' = \mu_1 - \frac{\mu_2^2}{\mu_4},\\
&\mathrm{Q}_2 = \mu_5 - \frac{\mu_2\mu_3}{\mu_1},\\
&r = -\frac{\mathrm{Q}_2}{\mathrm{Q}_1}, \text{ weight of } r = \mathrm{Q}_1,\\
&p = -\frac{\mu_3 + \mu_2 r}{\mu_1}, \text{ weight of } p = \mathrm{Q}_1',\\
&k = -\frac{1}{n}\Big\{[a]p + [b]r + [d']\Big\}, \text{ weight of } k = wn, \text{ nearly.}\\
&c = -\frac{1}{n}\Big\{[b]p - [a]r + [d]\Big\}, \text{ weight of } c = w'n, \text{ nearly.}
\end{aligned}
$$

If now these values of the unknowns are substituted in the original equations, and if we indicate by v and v' the residuals from the right ascension and declination equations respectively, then we must use as the sum of the squares of the residuals for the computation of the mean error of one equation of weight unity, the quantity :—

$$w[vv] + w'[v'v'].$$

In some cases it may seem desirable to compute the unknowns separately from the right ascensions and declinations in order to see if they agree within the limits of their probable errors. In doing this we can make use of the auxiliaries given above. The necessary formulæ are as follows :—

Right Ascension Equations.

$$\nu_1 = D - \frac{B^2}{A}, \qquad \nu_2 = E - \frac{BC}{A},$$

$$r = -\frac{\nu_2}{\nu_1}, \text{ weight of } r = \nu_1,$$

$$p = -\frac{B}{A}r - \frac{C}{A}, \text{ weight of } p = \nu_3 \text{ (}\textit{see below}\text{)},$$

$$k = -\frac{1}{n}\left\{[a]p + [b]r + [d']\right\}, \text{ weight of } k = n, \text{ nearly.}$$

Declination Equations.

$$\nu_3 = A - \frac{B^2}{D}, \qquad \nu_4 = E' + \frac{BC'}{D},$$

$$r = -\frac{\nu_4}{\nu_3}, \text{ weight of } r = \nu_3,$$

$$p = +\frac{B}{D}r - \frac{C'}{D}, \text{ weight of } p = \nu_1 \text{ (}\textit{see below}\text{)},$$

$$c = -\frac{1}{n}\left\{[b]p - [a]r + [d]\right\}, \text{ weight of } c = n, \text{ nearly.}$$

It will be noticed that the computation of the unknowns from the right ascension and declination equations combined, and treated as a single set of equations, is much less laborious than the determination from either set of equations alone. It follows that when a solution from the two sets of equations has once been effected, the combined solution can be worked out with very little additional trouble. We know of no good reason, *a priori*, why the separate solutions should bring out different values of the unknowns. Only by the discussion of a large number of plates, for each of which the two separate solutions as well as the combined solution have been made, can we settle this question. In performing such solutions, the weights and probable errors of the unknowns must always be worked out. For we should not be justified in drawing a conclusion, unless the differences between the values obtained from the separate solutions were appreciably greater than might reasonably be expected after a consideration of their probable errors.

Photographs of the Spectra of twenty-three characteristic Helium Stars; also Photographs of the Spectra of six Stars of the Third Magnitude, showing the transitions from type to type. By F. McClean, LL.D., F.R.S.

The photographs shown represent a series of spectra of twenty-three stars, characterised by lines associated with the new element, helium. They have been taken during the last twelve months in the course of photographing the spectra of the northern stars down to the third magnitude. The group thus selected corresponds almost exactly with Class I.*a* of Lockyer's "Classification of Stellar Spectra" (*Phil. Trans.* December 1892). Helium was not then in question, but soon after its discovery Lockyer further attributed the characteristic spectrum of this class to that element (*Proc. Roy. Soc.* May 9, 1895).

The larger series of spectra mentioned will include about 160 stars. Photographs are shown of the spectra of six stars of the third magnitude, illustrating the transitions from type to type. The types are the original ones of Secchi, but Type I. is subdivided into five sections, including that of helium.

A scale of wave-lengths has been constructed by the usual method which will be sufficient to identify the lines. Dunér's Bands are indicated on the spectrum of *α* Herculis.

The instrument used is a photographic telescope made by Sir Howard Grubb. The object glass is of 12 inches aperture and 11 feet 3 inches focal length; a prism of the same aperture, with a refracting angle of 20°, is mounted in a hinged frame in front of the object glass; the cell of the prism also rotates in the plane of the frame; by this means the adjustment of the prism both in position and either on or off the object glass is effected with facility. The telescope was completed in 1895 May.

1896 *May* 8.

Note.—A copy of the photographs will be deposited in the Library. They include the following stars:

Helium Stars.

1. Orion β	Mag. 1	13. Perseus δ	Mag. 3
2. „ γ	„ 2	14. „ ε	„ 3
3. „ δ	„ 2	15. „ ζ	„ 3
4. „ ε	„ 2	16. Lyra β	„ 3
5. „ ζ	„ 2	17. Pegasus γ	„ 3
6. „ ι	„ 3	18. Ursa Minor η	„ 2
7. „ κ	„ 3	19. Virgo α	„ 1
8. Auriga β	„ 2	20. Scorpio β	„ 2
9. Taurus β	„ 2	21. „ δ	„ 2
10. „ ζ	„ 3	22. „ π	„ 3
11. „ η	„ 3	23. „ σ	„ 3
12. Cassiopeia ε	„ 3		

Typical Stars.

Type	I. Canis Minor β	... ...	Mag. 3
„	I. Leo θ	... ...	„ 3
„	I. „ δ	... ...	„ 3
„	I. „ ζ	... ...	„ 3
„	II. „ ϵ	... ...	„ 3
„	III. Hercules α ...	... ...	„ 3

Diameters of Jupiter measured with the Filar and Double-image Micrometers at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

In 1895 June the results of the measures of *Jupiter's* diameters, made with a bi-filar micrometer attached to the 28-inch refractor, were communicated to the Society. At that time it was intimated that a few measures had also been made with the double-image micrometer, but that the results could not then be given, as the value of the micrometer-screw had not been ascertained. The observations have been continued, and the following are the results.

The method adopted was first to obtain a set of measures with the filar micrometer, and then a set with the double-image micrometer on the same evening. The 28-inch is well adapted for this, as the breech end is arranged for either direct or diagonal view by means of a plane mirror, which can be readily inserted or withdrawn. The bi-filar micrometer was mounted for direct view, and the double-image for diagonal view, by use of the plane mirror.

The adopted value of 1 rev. of the double-image micrometer is $4''\cdot151$, as ascertained by transits of a polar star on 1895 August 9.

The observations were made by Mr. Dyson and Mr. Lewis, and the results have been kept separate. Both observers made a few measures with a blue shade over the eye-piece, which made measuring easier.

The observations have all been reduced to mean distance 5·2028, and the correction for phase has been taken from Mr. Marth's Ephemeris in the *Monthly Notices*.

Measures by Mr. Dyson.

	Equatorial Diameter. Filar Micrometer.	Equatorial Diameter. Double-image Micrometer.	Filar – D. I.	Polar Diam. Filar Micrometer.
1896.	″	″	″	″
Feb. 6	38·455	37·837	+0·618	...
11	38·257	37·778	+ ·479	...
Mar. 2	37·974	37·758	+ ·216	...
23	38·368	38·353	+ ·015	35·926
25	38·380	38·224	+ ·156	36·128
30	38·601	38·697	– ·096	35·803
Apr. 15	38·335	38·398	– ·063	36·129
Mean	38·339	38·149	+ ·190	35·997

Measures by Mr. Lewis.

	Equatorial Diameter. Filar Micrometer.	Equatorial Diameter. Double-image Micrometer.	Filar – D. I.	Polar Diameter. Filar Micrometer.	Polar Diameter. Double-image Micrometer.	Filar – D. I.
1896.	″	″	″	″	″	″
Feb. 4	38·153	37·310	+0·843	...	...	...
6	·358	·235	1·123	...	...	...
10	·280	·688	0·592	...	...	...
18	·190	·579	0·611	...	...	...
22	·395	·832	0·563	...	...	...
Mar. 3	·439	·431	1·038	35·957	35·249	+0·708
5	...	...	...	36·030	...	...
27	·076	·630	0·446	36·170	35·176	·994
31	·138	·242	0·896	35·883	35·136	·746
Apr. 3	·051	·366	0·685	36·172	35·413	·759
8	·212	·355	0·857	35·881	35·541	·340
18	·115	·350	+0·765	36·029	35·655	+ ·374
Mean	38·219	37·456	+0·763	36·017	35·362	+0·655

If we compare the measures of the equatorial and polar diameters taken with the same micrometer it is clearly shown that the polar diameter is much more easy to measure; a fact which was felt during the observations. Of course this is in part due to the clock, and in part to the imperfection of the limb due to phase, this latter defect being very apparent where the east and west limbs were brought into contact in the double-image micrometer.

It will be seen that the filar micrometer not only gives more consistent results, but also shows less personality, the measures

of the two observers with it being in close agreement, while there is a large systematic difference between the measures made with the double-image micrometer.

Using, in addition to the observations above, three sets of observations made by Mr. Lewis in 1895, we get

		Filar Micrometer – Double-image Micrometer. Equatorial Diam.	Polar Diam.
		$''$	$''$
Mr. Dyson, 1896	... ...	+0·190	...
„ Lewis, 1896	... ...	+0·763	+0·655
„ „ 1895	... ...	+0·912	...
Weighted Mean	... ...	+0·593	+0·655

or combining both diameters:

$$\text{Filar} - \text{D. I.} = +0''\!\cdot\!609$$

The following comparison of the values obtained by different methods may be of interest:—

Heliometer.	Equat. Diam.	Polar Diam.	Double-image.	Equat. Diam.	Polar Diam.	Filar Micrometer.	Equat. Diam.	Polar Diam.
	$''$	$''$		$''$	$''$		$''$	$''$
Bessel	37·60	35·21	Kaiser	37·55	35·15	W. Struve	38·33	35·54
Winnecke	37·43	35·11	Main	37·91	35·67	Secchi	38·35	35·96
Johnson	37·38	35·13	Dyson	38·15	...	Barnard	38·52	36·11
Main	37·00	35·00	Lewis	37·46	35·36	Dyson and Lewis	38·27	36·01
	37·35	35·11		37·77	35·39		38·37	35·90

Royal Observatory, Greenwich:
1896 *May* 5.

Observations of Comets a 1896 (*Perrine-Lamp*) *and b* 1896 (*Swift*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks' Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

1896.	Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A. of ☄	Apparent N.P.D. of ☄	Comp. Star.
	d h m s		m s	s		′ ″	″			h m s	° ′ ″	
					Observations of Comet a 1896.							
Apr.	12 9 4 2	B.	+0 48·25	+0·01	9·6870	−10 55·9	−0·1	0·7119	4	4 34 2·93	49 10 8·5	*a*
	13 9 9 7	„	+2 14·33	0·00	9·6862	− 4 19·3	−0·1	0·7227	4	4 35 28·99	49 16 45·2	*a*
					Observations of Comet b 1896.							
Apr.	20 8 17 41	B.	+0 33·98	−0·06	9·6140	+ 8 43·4	+0·5	0·8153	2	...	...	*b*
	20 8 20 13	„	−0 14·44	−0·02	9·6129	+ 2 35·4	+0·3	0·8174	2	3 34 42·22	61 50 20·4	*c*
	20 8 24 13	A. C.	−0 14·39	−0·02	9·6115	+ 2 0·8	+0·2	0·8201	4	3 34 42·27	61 49 45·7	*c*
	20 8 25 15	„	−1 8·61	+0·10	9·6113	−11 41·0	−1·0	0·8206	1	3 34 41·76	61 49 48·4	*d*
	21 8 32 51	„	+1 53·33	+0·04	9·6164	− 6 4·7	−0·5	0·8240	6	3 32 55·98	59 7 12·6	*e*
	23 8 52 45	H.	+3 14·34	+0·02	9·6206	− 3 22·8	−0·4	0·8362	7	3 28 21·37	53 48 45·4	*f*
	26 8 45 38	B.	−1 0·63	+0·05	9·6554	−13 14·5	−1·0	0·8276	4	3 18 51·46	46 29 7·9	*g*
	26 8 45 38	„	−2 38·68	+0·03	9·6554	− 7 14·3	−0·6	0·8276	4	3 18 51·58	46 29 5·8	*h*
	26 9 6 1	A. C.	−2 41·38	+0·05	9·6331	− 9 7·2	−1·0	0·8467	2	3 18 48·90	46 27 12·5	*h*

Greenwich Mean Solar Time.					Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A. of ☄	Apparent N.P.D. of ☄	Comp. Star.
1896.	d	h	m	s		m s	s		′ ″	″			h m s	° ′ ″	
Apr.	27	8	33	10	B.	+1 43·57	−0·01	9·6763	+ 2 51·7	+0·2	0·8153	4	3 15 3·48	44 15 24·3	*k*
	28	8	34	59	A. C.	+1 30·09	0·00	9·6840	+ 1 21·7	+0·1	0·8173	5	3 10 51·03	42 7 26·0	*l*
	29	8	48	56	B.	+1 26·85	0·00	9·6757	− 2 9·2	−0·2	0·8325	4	3 6 16·22	40 5 31·1	*m*
May	1	9	24	38	H.	−3 41·99	−0·02	9·6211	+ 6 8·7	+0·7	0·8662	6	2 56 9·93	36 23 28·8	*n*
	2	9	29	33	B.	+0 16·70	−0·02	9·6097	+11 6·7	+1·5	0·8722	4	2 50 40·80	34 44 9·2	*o*
	3	9	23	24	C.	+0 13·09	0·00	9·6179	+ 2 30·7	+0·3	0·8698	4	2 45 0·24	33 12 44·4	*p*
	3	9	26	5	A. C.	+0 12·27	0·00	9·6113	+ 2 23·5	+0·2	0·8717	6	2 44 59·42	33 12 37·1	*p*
	4	9	5	4	B.	−0 50·68	0·00	9·6529	+ 1 9·6	+0·1	0·8574	4	2 39 7·43	31 48 36·2	*q*
	4	9	14	23	C.	−0 54·04	0·00	9·6324	+ 0 25·4	+0·1	0·8655	2	2 39 4·07	31 47 52·0	*q*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

April 12.—Comet exceedingly faint.

„ 13.—Comet extremely faint. Observations difficult and doubtful. Sky not quite clear.

„ 20.—Comet bright with condensation. Visible in bright twilight.

„ 21.—Sky hazy. Comet less clear than on previous night. Still readily visible in twilight.

May 1.—The comet had a distinct condensation.

The initials C., H., A. C., B., are those of Mr. Cowell, Mr. Hollis, Mr. Crommelin, and Mr. Bryant respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1896·0. h m s	Assumed N.P.D. 1896·0. ° ′ ″	Authority.
a	WB (2) IV. 658	4 33 14·30	49 21 18·3	Bonn Astr. Gesell. Catalogue, Paris Catalogue, 1875.
b	BD + 28° No. 560	3 34 8	61 42	Bonn Observations, vol. iv.
c	BD + 28° No. 563	3 34 56·58	61 47 53·6	Pulkova Catalogue (Romberg), 1875.
d	WB (2) III. 726	3 35 50·16	62 1 39·4	Weisse's Bessel (2).
e	Piazzi III. 96	3 31 2·55	59 13 27·0	Leiden Astr. Gesell. Zones 11, 243.
f	Lalande 6438	3 25 7·04	53 52 18·1	Lund. Astr. Gesell. Zones 75, 79, XV.
g	Groombridge 663	3 19 52·24	46 42 33·2	Greenwich Observations, 1894.
h	Groombridge 680	3 21 30·42	46 36 30·7	„ „ 1894, 1895.
k	OA (N) 3666	3 13 20·21	44 12 42·1	Bonn Astr. Gesell. Catalogue.
l	Groombridge 635	3 9 21·31	42 6 13·7	Greenwich Observations, 1891, 1893.
m	BD + 49°, No. 871	3 4 49·82	40 7 49·8	Bonn Astr. Gesell. Catalogue.
n	OA (N) 3433	2 59 52·57	36 17 28·4	Cambridge (U.S.) Astr. Gesell. Catalogue.
o	Lalande 5356	2 50 24·87	34 33 9·4	Helsingfors-Gotha Astr. Gesell. Catalogue.
p	Lalande 5202	2 44 47·99	33 10 21·3	„ „ „ „ „
q	BD + 58°, No. 519	2 39 59·06	31 47 33·9	„ „ „ „ „

BD + 28°, No. 563, is the double star Σ 429. The companion star is of the 11th magnitude.

Piazzi III. 96. The proper motion of $-0^s{\cdot}0077$ has been applied in R.A. deduced from comparison with Piazzi, Lalande, and Weisse's Bessel (2).

Royal Observatory, Greenwich:
1896 May 8.

Ephemeris of the Satellites of Mars, 1896–97. By A. Marth.

Professor Hermann Struve has been good enough to communicate, in advance of the publication of his observations of the satellites, the results which he has deduced for the longitudes l and mean motions n of the satellites, and also for the semi-axes a of their orbits. His values are ($l=w+\mathrm{N}$, w being the orbital longitude reckoned from N, the ascending node of the orbit on the plane parallel to the Earth's equator) for 1894 October 0·0 Greenwich :

Phobos $l_1 = 296^\circ\!\cdot20$ $n_1 = 1128^\circ\!\cdot84394$ $a_1 = 12''\!\cdot948$ at dist. 1.
Deimos $l_2 = 186\cdot38$ $n_2 = 285\cdot16194$ $a_2 = 32\cdot321$

Adopting these values, and referring the positions of the satellites to the assumed plane of the planet's equator, the data of the "Ephemeris for physical observations of *Mars*" become available, and the areocentric longitudes $l-\mathrm{L}$ of the satellites reckoned from the point of their orbits in opposition to the Earth, and the semidiameters a b of the apparent orbits, will be :

		Phobos.			*Deimos.*		
Greenwich Noon. 1896.	P+90°	a_1	b_1	$l_1-\mathrm{L}$	a_2	b_2	$l_2-\mathrm{L}$
	°	"	"	°	"	"	°
Sept. 9	56·58	13·49	−0·68	329·48	33·74	−1·71	250·11
11	56·92	13·66	0·60	66·33	34·17	1·49	99·54
13	57·27	13·83	0·51	163·21	34·60	1·27	308·99
15	57·62	14·01	0·42	260·11	35·05	1·05	158·46
17	57·97	14·19	0·33	357·03	35·51	0·83	7·96
19	58·32	14·38	0·25	93·96	35·99	0·62	217·48
21	58·66	14·58	0·16	190·92	36·48	0·40	67·02
23	59·00	14·78	−0·08	287·90	36·98	−0·19	276·58
25	59·34	14·99	+0·01	24·91	37·50	+0·02	126·16
27	59·67	15·20	0·09	121·94	38·03	0·23	335·77
29	60·00	15·42	0·17	219·00	38·58	0·43	185·41
Oct. 1	60·32	15·64	0·25	316·09	39·14	0·63	35·07
3	60·62	15·87	0·33	53·20	39·72	0·82	244·76
5	60·92	16·11	0·40	150·34	40·31	1·00	94·48
7	61·20	16·35	+0·47	247·52	40·92	+1·18	304·23
9	61·47	16·60	0·54	344·72	41·54	1·35	154·01
11	61·73	16·86	0·60	81·96	42·18	1·51	3·83
13	61·97	17·12	0·66	179·23	42·83	1·66	213·68

Greenwich Noon. 1896.	P+90°	a_1	b_1	l_1-L	a_2	b_2	l_2-L
				Phobos.		*Deimos.*	
	°	″	″	°	″	″	°
Oct. 15	62.19	17.38	0.72	276.54	43.49	1.79	63.57
17	62.39	17.65	0.77	13.89	44.17	1.92	273.50
19	62.58	17.93	+0.81	111.27	44.86	+2.03	123.46
21	62.74	18.21	0.85	208.69	45.56	2.13	333.46
23	62.88	18.50	0.88	306.16	46.28	2.21	183.51
25	63.00	18.79	0.90	43.67	47.00	2.27	33.60
27	63.09	19.08	0.92	141.22	47.73	2.31	243.74
29	63.16	19.37	0.93	238.81	48.46	2.33	353.92
31	63.20	19.66	+0.93	336.45	49.19	+2.32	304.15
Nov. 2	63.21	19.95	0.92	74.14	49.93	2.29	154.43
4	63.20	20.25	0.90	171.88	50.66	2.24	4.76
6	63.15	20.54	0.86	269.67	51.38	2.16	215.14
8	63.08	20.82	0.82	7.51	52.08	2.05	65.57
10	62.98	21.09	0.77	105.40	52.77	1.91	276.05
12	62.85	21.36	+0.70	203.33	53.44	+1.74	126.59
14	62.69	21.61	0.62	301.31	54.08	1.54	337.17
16	62.50	21.85	0.52	39.34	54.68	1.31	187.80
18	62.29	22.08	0.41	137.41	55.24	1.04	38.48
20	62.05	22.29	0.30	235.53	55.76	0.75	249.21
22	61.79	22.47	0.17	333.69	56.23	0.43	99.98
24	61.51	22.64	+0.03	71.89	56.64	+0.08	310.79
26	61.21	22.78	−0.12	170.12	56.98	−0.28	161.64
28	60.89	22.89	0.27	268.38	57.26	0.67	12.53
30	60.57	22.97	0.43	6.67	57.47	1.08	213.45
Dec. 2	60.23	23.02	0.60	104.98	57.59	1.49	74.39
4	59.88	23.04	0.77	203.31	57.64	1.91	285.35
6	59.53	23.02	0.93	301.65	57.60	2.34	136.32
8	59.19	22.97	−1.10	39.99	57.47	−2.76	347.30
10	58.85	22.89	1.26	138.33	57.27	3.16	198.29
12	58.51	22.77	1.42	236.66	56.98	3.55	49.28
14	58.19	22.63	1.57	334.98	56.61	3.92	260.25
16	57.88	22.45	1.71	73.28	56.16	4.26	111.21
18	57.58	22.24	1.83	171.56	55.65	4.58	322.15
20	57.30	22.01	−1.95	269.81	55.07	−4.87	173.06
22	57.04	21.75	2.05	8.02	54.42	5.13	23.94
24	56.79	21.47	2.14	106.19	53.72	5.35	234.79
26	56.57	21.18	2.21	204.33	52.98	5.53	85.60
28	56.37	20.86	2.27	302.42	52.20	5.68	296.38

Greenwich Noon. 1896.	P+90°		*Phobos.*			*Deimos.*	
		a_1	b_1	l_1-L	a_2	b_2	l_2-L
	°	″	″	°	″	″	°
Dec. 30	56·19	20·53	2·32	40·47	51·38	5·80	147·11
Jan. 1	56·03	20·19	−2·35	138·47	50·53	−5·88	357·79
3	55·89	19·85	2·37	236·41	49·66	5·93	208·43
5	55·77	19·49	2·38	334·31	48·77	5·95	59·02
7	55·68	19·13	2·38	72·16	47·87	5·94	269·57
9	55·61	18·77	2·36	169·95	46·96	5·90	120·06
11	55·55	18·41	2·33	267·69	46·05	5·84	330·50
13	55·52	18·05	−2·30	5·38	45·15	−5·76	180·90
15	55·50	17·69	2·26	103·02	44·25	5·65	31·25
17	55·51	17·33	2·21	200·61	43·36	5·53	241·55
19	55·53	16·98	2·15	298·16	42·48	5·39	91·80
21	55·57	16·63	2·09	35·66	41·62	5·23	302·02
23	55·62	16·29	2·03	133·12	40·77	5·07	152·19
25	55·69	15·96	−1·96	230·53	39·93	−4·89	2·32
27	55·78	15·63	1·88	327·90	39·12	4·71	212·41
29	55·88	15·31	1·80	65·23	38·32	4·51	62·46
31	56·00	15·00	1·72	162·52	37·54	4·31	272·47
Feb. 2	56·14	14·70	1·64	259·78	36·78	4·11	22·45
4	56·29	14·40	1·56	357·00	36·04	3·90	332·39
6	56·45	14·12	−1·48	94·19	35·32	−3·69	182·30
8	56·63	13·84	1·39	191·34	34·62	3·48	32·18
10	56·83	13·57	1·30	288·46	33·94	3·26	242·03
12	57·04	13·30	1·22	25·56	33·28	3·04	91·85
14	57·27	13·05	1·13	122·62	32·65	2·82	301·65
16	57·51	12·80	1·04	219·66	32·03	2·61	151·42

The differences of successive values of l_1-L vary between $2256°·85$ and $2258°·34$, and of l_2-L between $569°·43$ and $570°·99$.

The values of P, a, b, $l-L$ being interpolated directly for the times for which the positions of the satellites are required, the rectangular coordinates x and y of the satellites referred to the axes of the planet's disc, or their position-angles p and apparent distances s are found by means of the formulæ

$$x = s \sin(p-P) = a \sin(l-L)$$
$$y = s \cos(p-P) = b \cos(l-L) + a \cos B \,.\, \sin\gamma \sin(l-\Gamma),$$

where the inclinations γ and nodes Γ of the satellite's orbits referred to the assumed plane of the planet's equator have the following values :—

	Phobos.			*Deimos.*
	h m		h m	h m
1896. Dec. 12	8 22	*w*	16 1	18 33 *w*
13	11 8	*e*	18 48	9 41 *e*
14	10 6	*e*	17 45	15 57 *e*
15	9 3	*e*	16 42	22 13 *e*
16	8 0	*e*	15 39	13 21 *w*
17	10 47	*w*	18 26	19 37 *w*
18	9 45	*w*	17 24	10 45 *e*
19	8 42	*w*	16 21	17 1 *e*
20	7 39	*w*	15 18	8 9 *w*
21	10 26	*e*	18 5	14 25 *w*
22	9 24	*e*	17 3	20 41 *w*
23	8 21	*e*	16 0	11 50 *e*
24	7 18	*e*	14 58	18 6 *e*
25	10 5	*w*	17 45	9 14 *w*
26	9 3	*w*	16 42	15 30 *w*
27	8 0	*w*	15 39	6 39 *e*
28	6 58	*w*	14 37	12 55 *e*
29	9 45	*e*	17 24	19 12 *e*
30	8 42	*e*	16 21	10 20 *w*
31	7 40	*e*	15 19	16 37 *w*
1897. Jan. 1	6 37	*e*	14 16	7 45 *e*
2	9 24	*w*	17 4	14 2 *e*
3	8 22	*w*	16 1	5 11 *w*
4	7 20	*w*	14 59	11 28 *w*
5	6 17	*w*	13 56	17 45 *w*
6	9 4	*e*	16 44	8 54 *e*
7	8 2	*e*	15 41	15 11 *e*
8	7 0	*e*	14 39	6 19 *w*
9	9 47	*w*	17 26	12 37 *w*
10	8 44	*w*	16 24	18 54 *w*
11	7 42	*w*	15 21	10 3 *e*
12	6 40	*w*	14 19	16 21 *e*
1897. Jan. 13	9 27	*e*	17 6	7 30 *w*
14	8 25	*e*	16 4	13 48 *w*
15	7 23	*e*	15 2	4 57 *e*
16	6 20	*e*	14 0	11 15 *e*
17	9 8	*w*	16 47	17 33 *e*
18	8 5	*w*	15 45	8 42 *w*
19	7 3	*w*	14 43	15 0 *w*
20	6 1	*w*	13 40	6 9 *e*
21	8 49	*e*	16 28	12 27 *e*
22	7 46	*e*	15 26	18 46 *e*
23	6 44	*e*	14 24	9 56 *w*
24	5 42	*e*	13 21	16 15 *w*
25	8 30	*w*	16 9	7 24 *e*
26	7 27	*w*	15 7	13 43 *e*
27	6 25	*w*	14 5	4 51 *w*
28	5 23	*w*	13 3	11 10 *w*
29	8 11	*e*	15 50	17 29 *w*
30	7 9	*e*	14 48	8 38 *e*
31	6 7	*e*	13 46	14 57 *e*
Feb. 1	5 5	*e*	12 44	6 6 *w*
2	7 52	*w*	15 32	12 25 *w*
3	6 50	*w*	14 30	18 45 *w*
4	5 48	*w*	13 28	9 54 *e*
5	8 36	*e*	16 15	16 13 *e*
6	7 34	*e*	15 13	7 23 *w*
7	6 32	*e*	14 11	13 42 *w*
8	5 30	*e*	13 9	4 52 *e*
9	8 18	*w*	15 57	11 11 *e*
10	7 16	*w*	14 55	17 31 *e*
11	6 14	*w*	13 53	8 41 *w*
12	9 2	*e*	16 41	15 1 *w*
13	8 0	*e*	15 39	6 10 *e*
14	6 58	*e*	14 37	12 30 *e*

As it is, perhaps, feasible to secure trustworthy observations of the eclipses of *Deimos* near the beginning and ending of the next cycle of eclipses, I give, not only the Greenwich mean times of the satellite's conjunctions with the centre of the shadow cone, but also the computed semi-durations of the eclipses according to the data adopted in the present ephemeris, it being understood

that these semi-durations are liable to considerable uncertainty, and intended merely for guidance. It is essential that the observed disappearances and reappearances of the satellite should refer to corresponding phases, and it is to be hoped that all the most powerful telescopes will be made to contribute.

	Conj. or Middle of Eclipse.	Semi-duration.		Middle of Eclipse or Conj.	Semi-duration.
1896.	h m	m	1897.	h m	m
Nov. 6	10 6	...	Jan. 12	10 32	∓ 30
7	16 27	...	13	16 53	29
8	22 48	∓ 10	14	23 14	27
10	5 9	15	16	5 35	26
11	11 30	18	17	11 55	24
12	17 51	21	18	18 16	22
14	0 12	23	20	0 37	20
15	6 33	25	21	6 58	17
16	12 54	27	22	13 18	14
17	19 15	29	23	19 39	∓ 9
19	1 36	30	25	2 0	
20	7 57	∓ 31	26	8 21	

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVI. JUNE 12, 1896. No. 9

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

Rev. Frederick Lisle Bullen, the Rectory, Littleton-upon-Severn, Gloucestershire; and
Ernest W. Ellerbeck, the Observatory, Scarborough,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

George Alexander Sime Atkinson, 238 Newport Road, Cardiff, South Wales (proposed by H. W. Lloyd Tanner); and
John Burt Trivett, Computer, Trigonometrical Survey of New South Wales, Department of Lands, Sydney, Australia (proposed by Joseph Brooks).

Ninety presents were announced as having been received since the last meeting, including, amongst others:—

Chart of Southern Circumpolar Stars, presented by H. C. Russell; Stellar Spectra, photographed at South Kensington with the 6-inch prismatic camera, presented by J. Norman Lockyer; Enlargements from photographs of the region surrounding η *Argûs*, taken at the Royal Observatory, Cape of Good Hope, with exposures of 3^m, 1^h, $3^h\ 15^m$, 12^h, and 24^h, presented by David Gill.

An Answer to Certain Questions asked in the "Bulletin Astronomique," tome xiii, Mai 1896, *on Time Measurement.* By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

In the *Bulletin Astronomique*, tome xiii, Mai 1896, there is a short review of my paper on the Corrections of the Epoch and Mean Motion required by Hansen's Lunar Tables.

The writer makes no remarks whatever on the accuracy with which the observations of the Moon 1750–1892 are represented by Hansen's Lunar Tables with the corrected epoch and mean motion; and I presume, therefore, that he is satisfied upon that point. See *Monthly Notices*, vol. lv. No. 2, p. 58.

But, with the exception of a slight ambiguity in the definition of the physical meaning of the linear quantity, a, which satisfies the identity

$$f = n^2 a^3,$$

a concise, clear, and accurate statement of the views upon which my work is based is given; and some questions are asked and some formulæ brought forward which deserve careful consideration.

The notation adopted is that, for a selected epoch, n represents the Earth's mean motion in heliocentric longitude in the adopted unit of time measured from the mean equinox at epoch; ω, the constant angular velocity of the Earth about its axis in the unit of time; f, the accelerating effects of the Sun's mass taken as the unit of mass in the unit of time at the unit of length; a, a linear constant which satisfies the condition

$$\left(\frac{f}{n^2}\right)^{\frac{1}{3}};$$

p and q, the mean regressions in longitude and right ascension respectively of the true equinox from the mean equinox at epoch:

$$N = n + p : \Omega = \omega + q.$$

In order that these quantities may be combined in our mathematical investigations, it is, of course, absolutely necessary that n, ω, p, q, and f should be referred to the same unit of time, and f and a expressed in terms of the same unit of length, and that the same units should be employed for the expression of all the time quantities and linear quantities which appear in our formulæ.

The *exact* numerical values of the physical quantities represented by n, ω, p, q, f, and a will vary, according to well-known laws, with any changes which we may introduce into the units; and in tracing the effects of errors made we must proceed from exact equations to their approximate forms.

But if the units are not changed by us they cannot change.

The writer asks—

"Qu'est-on en droit de conclure lorsqu'on arrive, par une nouvelle discussion des observations, à une nouvelle valeur de $\frac{\omega}{n}$, l'invariabilité de la rotation de la Terre et de la constante de l'attraction étant admises? Indépendamment de tout choix d'unités, on a

$$\frac{\omega}{n} = \mathrm{K}, \qquad f = n^2a^3, \qquad \text{puis } \frac{\omega}{n'} = \mathrm{K}', \qquad f = n'^2a'^3,$$

d'où

$$\left(\frac{a'}{a}\right)^3 = \left(\frac{n}{n'}\right)^2 = \left(\frac{\mathrm{K}'}{\mathrm{K}}\right)^2;$$

on ne peut conserver la même unité de longueur si le demi-grand axe calculé est toujours pris comme unité ; il y a contradiction et discontinuité. Il est clair qu'on ne peut espérer assurer la continuité absolue des unités de temps et de longueur alors qu'elles sont empruntées, pour une certaine part, au mouvement de la Terre autour du Soleil.

"Pour suivre M. Stone dans son raisonnement, nous voyons bien que dans une première discussion $\frac{\omega}{n}$ doit être, pour une valeur adoptée de l'unité de longueur, indépendant de l'unité de temps ; la même chose aura lieu pour les nombres provenant d'une seconde discussion ; mais quel droit a-t-on de conclure *a priori* à l'identité des deux valeurs de $\frac{\omega}{n}$ quelle que soit l'unité de longueur?

"La substitution, en 1864, des Tables de Le Verrier à celles de Carlini a introduit une discontinuité dans l'unité de temps. Quelle a été, pour M. Stone, la modification de l'unité de longueur, et de quelle manière assure-t-il la continuité des mesures de longueur?"

The differences between the angles n', or mean motion in geocentric longitude of the Sun from true equinox minus mean precessional motion, thus found from a discussion of solar observations, and the angle n adopted to fix the scale on which the accelerating effects of the different masses are measured, will be due to one of the following causes or their combination :—

Firstly. The difference may be due to errors in the adopted value of the precession constant, p, employed to pass from the mean motion in longitude measured from the true equinox to that from the mean equinox. The adopted value of the precessional constant should in this case be altered ; and it is clear that we should not change the angle n adopted for the Earth's mean motion in heliocentric longitude, measured from the equinox at epoch in the unit of time, from n to n', and the accelerating

effects of the Sun's mass in the unit of time from n^2 or n^2a^3 to n'^2 or n'^2a^3, because n' thus found differs from n.

Secondly. The difference may be due to errors in the observations. In such a case it is also clear that we should not change the angle adopted for the Earth's mean motion in heliocentric longitude in the unit of time from n to n', and the accelerating effects of the Sun's mass in the unit of time from n^2 or n^2a^3 to n'^2 or n'^2a^3, but should wait for a longer series of solar observations.

Thirdly. The difference may be due to the neglect in our theoretical expression of the Earth's longitude of long inequalities of the form

$$P \sin (ct + d),$$

where P, c, and d are constants.

In this case, also, we ought not to change the angle adopted for the Earth's mean motion in heliocentric longitude from n to n', and the accelerating effects of the Sun's mass from n^2 or n^2a^3 to n'^2 or n'^2a^3; but the theory should be revised and the long inequalities computed on the scale fixed by the adopted angle n; and the effects should be duly allowed for in the discussion of the solar observations.

Fourthly. The difference between n and n' may be due to errors in our methods of finding the variable t from observation, or in referring the tabular positions of the centre of gravity of the Sun to the meridians of the observers. In this case, if t' is the value thus found, instead of t we should have, if the effects of the other sources of error were practically insensible,

$$(n' + p)t' = (n + p)t.$$

In such a case, as the variable t' is not the required variable t, we should, instead of altering n to n', correct the variable t'. It would not be of much practical importance whether we considered $n' - n$ as a correction on n, or $t - t'$ as a correction on t', if the disturbing effects of the planets were insensible; but as such is not the case, and these effects have to be estimated on the scale adopted in fixing the value of f, the use of t' for t will injuriously affect all our results proportionately to the magnitude of the factors of t, and corrections for the differences between t and t' must be applied in order to secure accuracy in the results. But perhaps it may be considered that no such error as the use of t' for t has been proved to have been made by astronomers. There is, however, no difficulty in proving that such errors are made in practice. But these proofs all turn upon the fundamental assumptions that *n represents the Earth's mean motion in longitude in the unit of time, and that we replace f by n^2a^3 in our mathematical work.*

In this case, if the physical quantities are denoted by n, ω, p, q, and f when referred to the unit of time fixed by the condition

$$f = n^2a^3,$$

and by n_0, ω_0, p_0, q_0, and f_0 when referred to a "unit of time" fixed by the condition that $f_0 = n_0^2 a^3$, where n_0 is such that

$$\omega_0 + q_0 = 365{\cdot}25 \times 2\pi + n_0 + p_0,$$

or

$$\Omega_0 = 365{\cdot}25 \times 2\pi + N_0,$$

we shall have, with *exact* quantities,

$$\frac{\omega_0}{\omega} = \frac{n_0}{n} = \frac{q_0}{q} = \frac{p_0}{p},$$

$$\therefore\ \omega + q = 365{\cdot}25 \times 2\pi \times \frac{n}{n_0} + n + p,$$

$$\text{or } \Omega = 365{\cdot}25 \times 2\pi \times \frac{n}{n_0} + N,$$

$$\text{or } \Omega = 365{\cdot}25 \times 2\pi + N + 365{\cdot}25 \times 2\pi \,.\, \frac{n - n_0}{n_0}.$$

These formulæ also follow directly from the difference between the exact ratio of the mean sidereal day to the mean tropical year at epoch and that assumed by astronomers in practical work.

But astronomers in practical astronomical work erroneously replace

$$\Omega = 365{\cdot}25 \times 2\pi \times \frac{n}{n_0} + N,$$

$$\text{by } 365{\cdot}25 \times 2\pi + N,$$

although different values of n are adopted for the same epoch. And, as a consequence of the error thus made, when referring the positions of the centres of gravity of the Sun, Moon, and planets to the meridians of the observers, and in finding the time, t, from observation, they have taken out the *tabular* R.A. of the meridian, expressed in circular measure, for the time, t, in error by

$$-2\pi \,.\, 365{\cdot}25 \,.\, \frac{n_0 - n}{n_0} \,.\, t;$$

and all the terms in our theoretical expressions which contain t as a factor are thus proportionately affected with errors due to the neglected term.

It is true that the exact value of n_0, and therefore of

$$\frac{n_0 - n}{n_0},$$

for an assigned value of n, and a definite epoch, is at present unknown; but if we include in the expressions for t, as directly found from observation, the effects of the neglected terms, we have the means of finding n_0 by continuous approximation from

the observations. And, although $n_0 - n$ is at present unknown, we know the difference in the errors made with two different adopted values n and n', viz. $n' - n$; and I have shown that the effects of the neglected terms due to the difference $n' - n$ for the values adopted for the Sun's mean motion in longitude in the unit of time in the solar tables which were employed, before and after 1864, to bring up the stellar places from one epoch to another, to reduce the geocentric places to heliocentric places, to refer the positions of the centres of gravity to the meridians of the observers, and to find the time, t, are sufficient to perfectly account for the increase in the errors of Hansen's Lunar Tables in longitude, which, as a matter of fact, set in *per saltum* about 1864, and has continued since, until it now amounts to about $22''$.

I hope that I have here given a clear and distinct answer to the question, "What conclusion ought to be drawn when a new value n' of n results from a new discussion of solar observations?"

The difference between n and n' will be due to the causes which I have indicated, and in none of these cases is there any necessity for changing the numerical value of the accelerating effects of the Sun's mass at the unit of length in the unit of time; nor is there any means of evading the consequences if we make the change.

I now proceed to show why the writer of the review is led to physical inconsistencies by changing n into n'.

If the conditional equation

$$f = n^2 a^3$$

is true when any unit of time is adopted to measure the Sun's mean motion in longitude, which is here denoted by n, and any unit of length to measure the linear quantity, denoted by a, it is certainly true for any units of length and of time which we can adopt.

For f, the measure of the accelerating effect of the Sun's mass—

$$\propto \text{ as } \frac{(\text{the unit of time})^2}{(\text{the unit of length})^3},$$

and

$$n^2 \propto (\text{the unit of time})^2,$$

and

$$a^3 \propto \frac{1}{(\text{the unit of length})^3}.$$

The unit of time in terms of which f, n, ω are expressed is a matter of choice on the part of the mathematician, but *if n does express the Sun's mean motion in geocentric longitude in the unit of time* we certainly fix the unit of time when we assign a definite value to n, and the same unit of time must be adopted for the expression of f and ω. And, with regard to the unit of

length, we can, if we please, adopt the linear quantity, which satisfies the condition of being equal to

$$\left(\frac{f}{n^2}\right)^{\frac{1}{3}}$$

as the unit of length; and, with this unit, we have the accelerating effects of the Sun's mass accurately measured by n^2. *If we adopt these units in our mathematical work we clear f from fallible errors of determination, and it is a constant throughout our work*; but we have to express all the time quantities and the linear quantities in terms of the units of length and of time thus deliberately selected, and we must accept any practical inconveniences which may result from the choice of units thus made.

But we need not select this particular unit of length. We can select a, the linear constant introduced into the primary differential equations of the Sun's geocentric motion, or the semi-axis major of the undisturbed orbit as our unit of length. In this case we shall have, if ν_3 denotes the ratio of the mass of the Earth to that of the Sun,

$$f = n^2a^3 = \frac{n^2a^3}{1+\nu_3}\left(1+\frac{\delta a}{a}\right)^3 = \frac{n^2}{1+\nu_3}(1+\delta a)^3$$

when a is taken as the unit of length.

The correction δa will be a function of the disturbing masses, and must be found in terms of the adopted unit of length from the mathematical investigations. This is the method which Le Verrier followed, and it is clear that any change which we may make in n will change the unit of time in terms of which

$$\frac{n^2}{1+\nu_3}\cdot(1+\delta a)^3$$

will measure the accelerating effect of the Sun's mass, but not the unit of length; and that the unit of length is different when we adopt

$$n^2a^3,\quad n^2,\quad \frac{n^2}{1+\nu_3}(1+\delta a)^3$$

for the accelerating effects of the Sun's mass at the unit of length in the unit of time; and *neither the unit of length nor the unit of time can change unless we change them.*

Now the writer is directly led to physical inconsistencies and discontinuities, because, after adopting values of n, ω, and f, referred to a definite unit of time fixed by the condition that the assigned angle n shall be the Sun's mean motion in geocentric longitude in the unit of time, he assumes that he can adopt for the mean motion of the Sun in geocentric longitude in the unit of time an angle n' instead of n, and can yet assume that the values of ω and f are not proportionately changed. The conditions thus introduced are physically impossible relations between ω, f, and n'.

The results thus arrived at agree identically with those which I have obtained. I have shown that, unless we admit the possibility of discontinuities in our unit of time, we must, when we change n to n', change ω to ω', and f to f', such that

$$\frac{n}{n'} = \frac{\omega}{\omega'} = \frac{\sqrt{f}}{\sqrt{f'}}.$$

Similar remarks refer to the unit of length.

The linear quantity a cannot be changed without changing the unit of length, and thus changing the *numerical measure* of the accelerating effects of the unit of mass at the *unit of length* in the unit of time.

If the mean sidereal day were taken as the unit of time, the angle n in terms of this unit would become an angle determinate only as a fallible quantity from observation. It would be liable to not only mere chance errors of observation, but to the effects of any neglected long inequalities in the expression of the Sun's longitude: and the use of n^2a^3 for f under such circumstances in our mathematical work would render f a variable quantity instead of a constant. And the errors thus introduced in our mathematical work would be of the same class, but of a more involved character, as those which led to the prolonged discussion on the value of the secular acceleration of the Moon's mean motion.

My contention here is that neither the mean sidereal day nor any assigned definite multiple of that interval of time is adopted as the unit of time in the formation of the differential equations of motion of gravitational astronomy, or that the integrations are erroneously carried out in terms of the variable. Similar remarks apply to the adoption of the physical "mean solar day." The angle n_0 required to fix such a unit of time is at present unknown.

The mathematical results obtained by the writer of this review agree with those which I have obtained; and it would appear that the choice lies between astronomers accepting the fact that they have overlooked and neglected the effects of the small terms

$$\frac{n_0 - n}{n_0}$$

in finding their time from observation, or assuming the possibility of the investigations of mathematical astronomy being carried on with units of length and of time, which are discontinuous, and of which the laws of discontinuity are unknown.

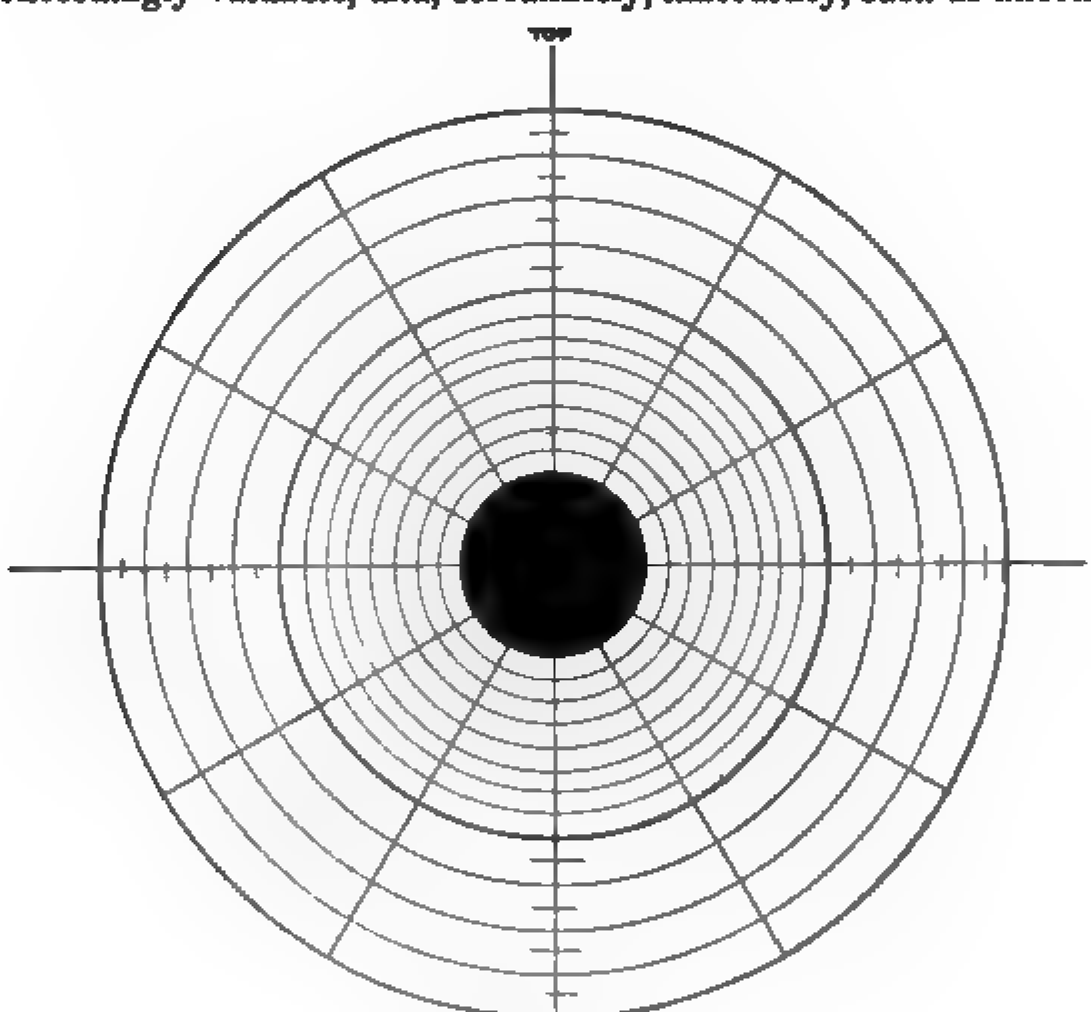
The effects of the errors indicated in finding the variable, t, from observation, when $n_0 - n$ is not zero, must be duly allowed for in our work before any inferences respecting the inaccuracy of the law of gravitation or sensible instability in the rotation of the Earth about its axis can be discussed with advantage.

Solar Eclipse without Instrumental Means. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

A considerable number of persons keenly interested in astronomy, but unprovided with instrumental means, will, if the weather prove favourable, see the eclipse of 1896 August 9 in Norway.

It has occurred to me that such observers might render a service to astronomy if they were to follow out the plan I recommended, and which was carried out under somewhat similar circumstances for the observations of the eclipse of 1874 in South Africa.

The corona consists of a comparatively bright inner part lying close to the Sun, surrounded by a much fainter mass of luminous matter of vast extent, and generally of most irregular form, which does not yet appear to have been successfully photographed to its full extent. Accurate drawings of the outline will be exceedingly valuable, and, fortunately, inaccuracy, such as affects



the scientific value of the drawings, can be avoided if the following precautions are taken: Those persons who intend to make sketches should provide themselves with a sheet of paper about 9 inches wide by 12 inches long, having upon it a black disc

$1\frac{1}{4}$ inch in diameter to represent the Moon, from the centre of which concentric circles and straight lines at angles of 30 degrees are drawn, as in the accompanying diagram, to place correctly the outlying portions of the corona in position and to scale. A weight must be suspended by a string in such a position that the observer can see it hanging over the Sun's centre, and the diagram upon which the drawing is to be made so placed upon a convenient stand that the line marked "top," "bottom" shall be in the plane passing through the observer's eye, the string, and the Sun's centre; the end marked "top" of the diagram must correspond to the top of the string.

It may be desirable that two or three minutes before totality the observer should cover his eyes, to render them sensible to feeble light, leaving it to a friend to warn him when totality begins; but this should not be carried far enough to strain the eyes.

On the Equipment of the Astrophysical Observatory of the Future. With two Appendices: Appendix I.—On the Support of Large Specula; Appendix II.—On Making the Siderostat an Instrument of Precision. By G. Johnstone Stoney, M.A., D.Sc., F.R.S.

Hitherto the scrutiny of separate celestial objects, or of fields of view, whether by eye observations, with the photographic camera or through the spectroscope, has been carried on amidst practical difficulties with equatorial telescopes expensively mounted and under cumbrous movable domes. To the eye end of the telescope the camera, spectroscope, or other apparatus has had to be attached under conditions not easy to secure, and the apparatus can only be of such a kind as the telescope is able to carry, and which may with safety be borne by the equatorial movement into positions which are often inconvenient and always changing. These limitations preclude the use of delicate apparatus, such as micro-radiometers, which can only be set up upon a fixed support, or of complex appliances, such as the apparatus for producing monochromatic images, recently described by Captain Abney, and from the employment of which, or of other apparatus of a like kind, we may reasonably look for a great accession to our knowledge of the physics of the Sun.

However, the extraordinary success with which instrument makers can now figure large flat mirrors, the much greater facility and certainty with which they can be resilvered, and the possibility of supporting them in all positions with the requisite delicacy and without risk of shifting their line of collimation, by the arrangement described below in Appendix I., give an opportunity of remedying all this. We have it thus within our power

to equip an equally efficient and much more convenient astrophysical observatory at a less cost than hitherto, or by an equal expenditure to furnish one which can accomplish much more.

There are four ways in which the flat speculum may be employed: in the ordinary siderostat, described early in the eighteenth century by s'Gravesande; in the polar siderostat; in the modification of the polar siderostat, suggested some years ago by Sir Howard Grubb, in which the objective is outside the flat mirror, and is, along with it, carried round by the polar axis; or, finally, in that very meritorious instrument the cœlostat, an instrument of which the polar axis is driven round once in forty-eight hours. An instrument driven in this way was constructed and described by Mr. Conrad Cooke many years ago, but its real value was not known till it was pointed out by M. Lippmann last year, that the image furnished by it does not rotate in the field of view if the mirror be placed strictly parallel to the polar axis. All of these have their special advantages and disadvantages, and it is probable that a fully-equipped astrophysical observatory should possess more than one of them.

For photographic work the polar siderostat, whether in the usual or in Sir Howard Grubb's form, and the cœlostat, offer the greatest advantages in dealing with all parts of the sky, except a small region in the immediate neighbourhood of the pole, for which special provision, not difficult to contrive, would have to be made.

With the polar siderostat the telescope must be placed in or parallel to the polar axis. The telescope may be either stationary in the axial position or carried round by the axis, but, in any case, the camera must be attached to the moving axis and rotate with it, in order that the image may remain in one fixed position upon the photographic plates. A spectroscope when used with a polar siderostat may be set up in one fixed position whenever, as is usual, the rotation of the image in the field of view is immaterial.

Astronomers have a well-founded distrust of convertible instruments; but the structural provision which would have to be made in order to convert a polar siderostat into a cœlostat is of such an extremely simple and unobjectionable kind that it is probable that the same instrument could safely be made to serve in both capacities. When used as a cœlostat, the telescope with its camera, or other apparatus, is to be mounted on a nearly horizontal table, which can traverse round in azimuth, and slope upwards and downwards through a few degrees. There are many kinds of bulky or delicate apparatus which would admit of these motions, although they could not be carried into the positions into which an equatorial would sweep them; so that the range of work which can be done in the observatory will be increased.

When, however, we want to use the most powerful spectroscopes, such as Rowland's largest concave gratings, or very deli-

cate instruments, such as Professor Boys's radio-micrometer, the ordinary siderostat, s'Gravesande's siderostat, if it can be perfected, offers immense advantages, since the telescope and associated apparatus can remain immovable in a horizontal position, while all requisite adjustments are made upon the siderostat. These are matters of great practical convenience. It is to be remembered that the only defect which the siderostat has, namely, that the image furnished by it slowly rotates in the field of view, is of no detriment for stellar spectroscopy. By employing a s'Gravesande's siderostat, therefore, we may bring much more powerful appliances than heretofore to bear on the spectroscopic examination of stars, and we shall use them under the most convenient conditions.

The only inferiority of this instrument to the polar siderostat as an instrument of precision lies in the sliding motion which has always hitherto been made use of in it. But a model which was exhibited at the meeting, and which is described in Appendix II., shows that this sliding motion may be got rid of, and a continuous motion substituted, with details that possess every quality which is essential for extreme astronomical precision. With this improvement the s'Gravesande siderostat becomes an instrument that can be relied on in the astronomical observatory, and will be found probably much the most useful form of siderostat for all work which is compatible with the image rotating in the field of view.

What I suggest accordingly is, that the astrophysical observatory of the future be furnished with a polar siderostat convertible into a cœlostat, and where practicable with an ordinary siderostat also, instead of with an equatorial; and that whatever is saved by the less expensive mountings and roofs, be employed in increasing the size and excellence of the mirrors and objectives. It is anticipated that in this way an astrophysical observatory may be constructed for carrying on the whole of the existing work with increased facility, and that it will besides bring within our reach important new branches of work, and extensions of the older work, which have hitherto been impracticable.

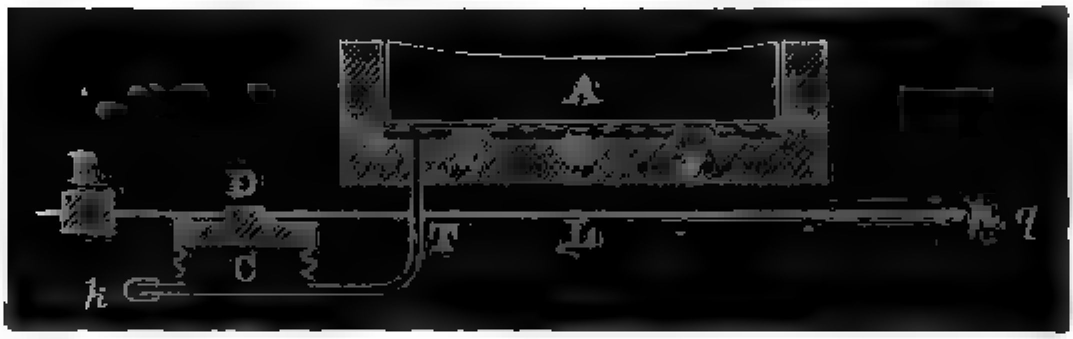
APPENDIX I.

On the Support of Large Specula.

The chief obstacle to the use of large specula in the astrophysical observatory, and especially for photographing the heavens, is that shifting of the line of collimation to which they are liable when the mirror is made to follow the motion of the celestial object.

The difficulty in preventing this shifting of the line of collimation arises out of the necessity for applying an extremely equable pressure over the back of the mirror which shall vary in amount according as changes in the altitude bring more or less

of the weight of the speculum to act upon its back support; and the necessity for avoiding the pinch to which changes of position or unequal expansion are apt to give rise. In the case of large specula the support is usually "a bed of levers," which, to act with the requisite delicacy, must somewhat yield; and when it yields, it is difficult—and with the largest mirrors practically impossible—to prevent some slight shifting of the plane of the mirror, which, of course, alters the line of collimation, and, for example, makes it impossible to take the best photographs with these great instruments, which otherwise would be the best for the purpose.



In the proposed arrangement the bed of levers is got rid of, and a pneumatic support takes its place. The mirror is mounted in a cell which takes the edgewise pressure, and in which it may be held without pinch and as nearly rigidly as an object-lens, if at the same time the back of the mirror receives such an equable pressure over its whole surface as shall exactly balance the normal component of its weight.

This is accomplished as follows. The cell is divided into two chambers, A and B, in the upper and larger of which the mirror is situated, resting on three props, x y z, of which two are shown in the figure, and which come into action only when there is insufficient air in the lower chamber.* An air-tight partition of thin flexible sheet-metal, represented in the figure by the dotted line m n, is to separate the lower from the upper chamber. This partition should be corrugated somewhat like the top of the vacuum chamber of an aneroid barometer, to provide for the difference in expansion between metal and glass. The lower chamber B may be very shallow—in fact, a mere chink. It communicates through the tube T with the regulator C, which is another air-chamber. In many cases this regulator may simply be a common air-cushion of appropriate size, in which the air is compressed by the disc D, which is forced against it by the lever

* Or, if it be found that there is risk of strain beyond the limit of elasticity when there is insufficient air, a bed of levers within the chamber B may take the place of the three props. When the proper amount of air is introduced it just relieves the pressure from the props or bed of levers, so that the latter only act while there is insufficient air.

L, at one end of which is the counterpoise E, and at the other end of which are the pivots p and q, one of which is above and the other under the plane of the section represented in the diagram. The whole of this apparatus is to be attached to the cell carrying the speculum, so as to accompany it in its motions. By this arrangement only one component of the weight of the counterpoise and lever acts on the regulator, the components which are parallel to the plane of the speculum being supported by the pivots p and q. In this way the air in the regulator, and consequently the air in the chamber under the mirror, is in all positions compressed in exactly the proper degree to support the normal component of the weight of the mirror. K is a nozzle through which air may be pumped in, if in the course of time there should be some leakage. The amount of the compression and the variations of pressure, even for so great and so heavy a mirror as either of Lord Rosse's two great six-foot mirrors, one of which weighs four tons and the other three tons and a half, are so slight that they would in no sensible degree interfere with the accuracy of the working of the arrangement; and with it the line of collimation can be kept as rigidly fixed in relation to the cell as any astronomical work requires. The mirror, of course, will need to have been ground and polished upon a similar support, as large mirrors do not admit of any alteration being made in their support without deformation.

In a small working model which was shown at the meeting of the Society, a large ordinary air-cushion took the place of the chamber B and the regulator C. It was in a chink between two boards, in the upper of which boards were two circular holes; the larger one to allow a twelve-inch speculum to rest upon the air-cushion, and the smaller one for a wooden disc pressed against the air-cushion by the counterpoise and lever. The boards prevented any expansion of the air-cushion, except where the mirror and counterpoise reached it.

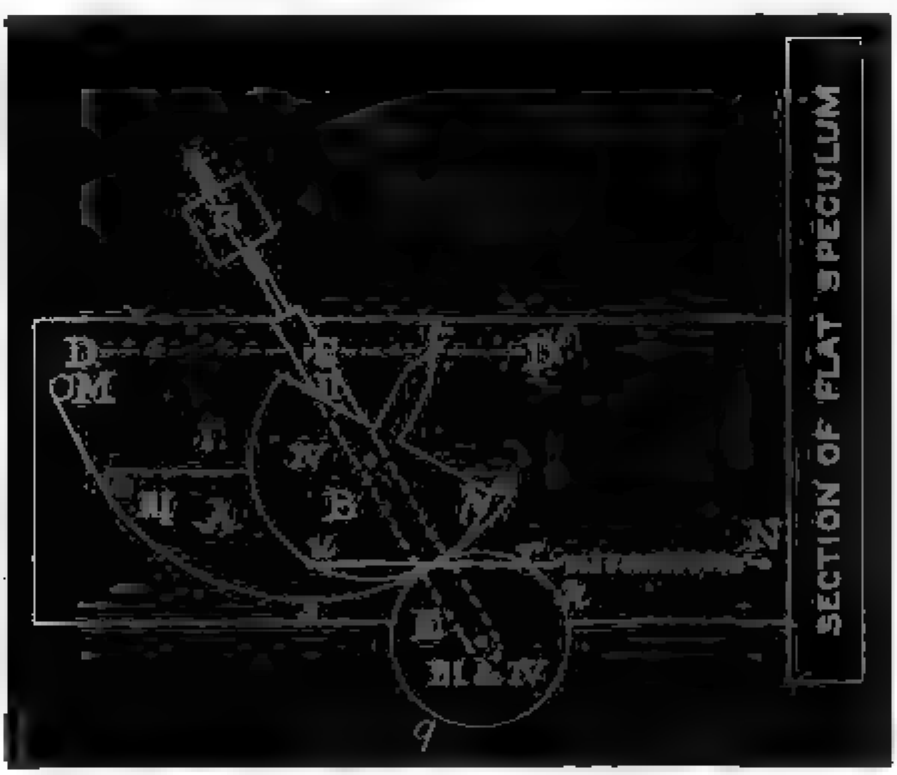
Appendix II.

On making the Siderostat an Instrument of Precision.

When the difficulties in the support of the flat mirror are fully got over (see Appendix I.), the chief obstacle to making the siderostat an instrument of astronomical precision lies in the necessity of providing a rectilinear motion between the mirror and that arm which the clockwork acting on a polar axis keeps pointed either directly towards or directly away from the celestial object, while the latter travels across the sky in its diurnal course. Hitherto this rectilinear motion has always been effected by a tube fitted upon the end of the arm sliding along a straight bar attached to the mirror, an arrangement which cannot always be relied on for extreme astronomical accuracy. Attempts have been made to substitute a continuous motion for this sliding

motion, but hitherto without getting over the practical difficulties. But the following arrangement appears to meet these difficulties so satisfactorily, that with it s'Gravesande's original pattern of siderostat, now commonly known as Foucault's, or that other type which the present writer adopted in the small "local heliostats" intended for use in physical laboratories, can either of them be made instruments of as great precision as the equatorial telescope.

In order to provide the rectilinear motion, use is made of the well-known kinematical principle, that if a circle roll on the inside of another circle of double its diameter, each point on the circumference of the smaller circle will traverse a diameter of the larger circle backwards and forwards. A working model was exhibited to show how this principle is to be applied, the essential



parts of which are represented in the accompanying diagram. M N is a sole-plate to which the apparatus is attached, and it lies at the lowest level in the diagram, which is indicated by the number I upon it. Next above it, indicated by the number II, is the lever E F, which turns on the pivot C standing up from the sole-plate. In the next tier, indicated by the number III, stands A, an arc of the larger circle, which is attached to the sole-plate, but propped up from it by two blocks at its ends, so as to leave space enough between for the lever E F to play. The pivot C is at the centre of this larger circle, and D D' is one of its diameters. In the next tier, indicated by IV, is the small circle B of half the diameter of the larger. It turns on a pivot which stands up from the lever E F. Another pivot, standing up from

this lever, carries the idle drum E, which is rather more than twice as thick as A or B, so that the lower part of it is at the level of tier III and the upper part at the level of tier IV. Round the upper part passes a flexible steel band which is fastened at k, and from that goes in the direction $k\,q$ to p, where its other end is fastened to the wheel B. At the lower level another steel band is fastened at k, which passes in the direction $k\,r\,s$, round the larger wheel on to M, where it is fastened to the sole-plate by some contrivance which allows it to be a little lengthened or shortened at will. By this arrangement, if both bands are kept taut, the wheel B is made *to roll on the inside* of the wheel A. The steel bands are kept taut by the spring Nu, which is attached to the sole-plate at N, and to the wheel B at that point on its circumference which is opposite to the pointer t. This point u, like every other point on the circumference of the wheel B, traverses a portion of a diameter of the larger circle A, which in this case is a short part of the vertical diameter in the figure; and if N is placed sideways at the height of the middle of this short part, the spring will scarcely lengthen or shorten during the motion, so that even if strong, it neither throws a sensible amount of energy into the moving system nor withdraws sensible energy from it during the motion: in other words, the spring may be strong enough to effectually prevent all back-lash, and will notwithstanding allow the movement of the apparatus to be sensibly smooth and unimpeded throughout its whole range, a matter of importance in an instrument to be driven by clockwork.

During the motion, t, which is also a point on the circumference of B, traverses one of the diameters of the larger circle A, and this can be made any desired diameter, D D′, by adjusting the length of the second steel band at M, where provision for making this adjustment can conveniently be made. In the Foucault type of siderostat it is, of course, to be adjusted so as to be perpendicular to the reflecting surface of the flat mirror.

The whole arrangement has, therefore, to be attached to the back of the cell carrying the flat mirror. If rigidly attached, a universal joint of some kind must be provided where the end of the arm carried by the polar axis is connected with the end of the pointer t, which is the point that is constrained to move in a straight line perpendicular to the mirror. If attached in this way, the planes of the wheels A and B continue vertical throughout the motion. Another mode of attachment is to mount the whole so as to swing on a straight bar attached perpendicularly to the back of the mirror, so that the axis of the bar shall occupy the position marked in the figure by D D′. In this case a ring, which shall pass round this bar without touching it, must take the place of the pointer t, and with this the arm of the polar axis may be more simply connected. If mounted in this way the new apparatus will shift part of the way round the bar during the motion. But whichever arrangement is adopted, one counterpoise F will balance the moving parts in all positions. It will probably be

found convenient to duplicate the lever E F, and place half or a certain portion of the counterpoise at the end of each duplication, so as to keep the counterpoise clear of the polar axis and its arm in every position.

On the Importance of Accurately Observing the Leonids this Year.

By G. Johnstone Stoney, M.A., D.Sc., F.R.S.

The *Leonids*, the great November swarm of meteors, is the meteoric stream about which astronomers know most.

This great body of meteors traverses an immense oval orbit which, near its farther apse, crosses the path of the planet *Uranus*, and near its perihelion crosses the earth's path. The meteoric orbit does not intersect the orbits of the intermediate planets, *Saturn*, *Jupiter*, and *Mars*, owing to the considerable inclination of its plane. Round this great inclined orbit the meteors glide in a stream which lengthens as it moves inwards towards the Sun, and becomes shorter during each outward journey. Where the swarm passes the Earth it is about 100,000 miles thick, and of such a length that, though it travels at the rate of 27 miles a second, the great procession takes two years to pass us, and when its hinder part is still with us, its front will have reached to between the orbits of *Jupiter* and *Saturn*. Nevertheless, although so immensely long, it extends over only a portion of the circumference of its own great orbit, which it takes about a third of a century to traverse.

The front of this great swarm will next reach the Earth's orbit late in the spring of 1899. The Earth will then be in a distant part of its orbit, but in the middle of the following November and in November 1900 it will pass obliquely through the mighty stream, and on each of these occasions there will be an astounding rain of meteors, probably for about five hours, on the whole of the advancing side of the Earth.

Now, when we have regard to the fact that these meteors are not visible in outer space, and that we can only, and only for a second or two, observe that small proportion of them which happen to flash into some part of our small atmosphere, it is truly astonishing that it has been possible to gain so much knowledge of their movements and history.

Astronomers may be divided into two classes—chamber astronomers and observers. Sir Isaac Newton was the greatest of the former class, and the late Professor Couch Adams was one of the greatest of modern times. To him and to Professor H. A. Newton, of New Haven, we chiefly owe the great discovery. Before the visit of the meteors to the Earth in 1866 and 1867, Professor Newton pointed out how to deal with the problem, but it was by a process so difficult that it remained doubtful whether

any mathematician could successfully grapple with it. He also called the attention of practical astronomers to a datum which was wanted and which could be supplied by observation. Owing to his forethought, the requisite observations were made on the morning of 1866 November 14 (civil time), and immediately afterwards Professor Adams set to work to employ the material so furnished in the way that Professor Newton had indicated. In the following May, after five months of arduous labour, he was able to announce what the real orbit of the meteors is.

The *Leonids* are at present advancing inwards towards the Earth. They cannot be seen, but their position can be calculated, and it would be possible to determine to what part of the Earth's orbit they present themselves most endlong. Though not visible to the eye, it is quite possible that they may be photographed, and we have among us astronomers especially competent to make the attempt.

There is a comet in the track of these meteors. It will reach its perihelion before them. All the information about this comet which industry can glean from former observations should be thoroughly elaborated and put together in time to make full use of it when the comet reappears; and when that occurs all the elements of the comet's orbit, and, if possible, its apsidal motion, should be determined with the utmost precision, to aid in tracing whether the comet was once perturbed by the Earth, like the stray *Leonids* seen annually. Whatever knowledge, too, spectroscopic scrutiny would furnish may prove of use.

A desideratum of special theoretical importance, and one which requires that observers should at once be on the alert, is as exact a determination as possible of the day and hour of apparition, and of the path in our atmosphere, of such outlying portion of the swarm as may precede the principal stream or follow it by one or more years. On the last occasion observations of this kind were made chiefly after the great visitation had taken place. It is of importance that on this occasion equally full observations shall be made in the years preceding it, *i.e.* in the present year and in 1897 and 1898. It is desirable that, wherever possible, concerted observations shall be made from different stations; that they be much more exact than heretofore, and therefore made photographically when possible; also, that they shall extend to a few days before and a few days after the 14th and 15th of November, inasmuch as we do not yet know on what dates to expect the advent of the avant-couriers of the principal swarm.

It is necessary here to keep in view the distinction between real advanced members of the great swarm, and mere scattered *Leonids*, a few of which are seen every year. The true forerunners of the swarm will, presumably, present themselves only within a brief definite period of time, extending to something like five hours, whereas a sprinkling of sporadic meteors may be met with for several days. These stray meteors seem to be meteors near to which the Earth chanced to pass in one or other

of its transits through the swarm, and which were by the Earth deflected a little from the true meteoric orbit. It does not appear that any special use can be made of observations upon these scattered *Leonids*.* But accurate observations of the true avant-couriers are specially wanted, and the importance of these observations will appear from what follows.

We come now to the chief matter which should be kept in view. The meteors are not a compact cluster, but drawn out along a considerable portion of their orbit. This, as Schiaparelli pointed out, is consequent upon there being differences between the periodic times of the individual meteors. Those that come round fastest get ahead, those that have the longest periodic time lag behind. Thus the stream is one that is lengthening century after century, and we can look back to a time when the whole must have been a compact cluster.

Now there is reason to conjecture that it was in the early spring of the year A.D. 126 that this lengthening out of the group commenced; for Le Verrier discovered that in the end of February or beginning of March of that year the meteors and the great planet *Uranus* were both at the point where their orbits intersect —an event which has not happened since. This raises a well founded suspicion that up to that year the meteors may have been a compact cluster travelling inwards towards the Sun; that in that year they stumbled on this great planet; and that it remained long enough in their vicinity to exercise such an influence over them as drew them out of their previous course and started them in the new orbits round the Sun, which they have since for nearly eighteen centuries pursued. If it acted in this way the planet would inevitably perturb the several members of the group a little differently, so that their new orbits would not be precisely the same. If, in consequence of this their periodic times vary from a week more to a week less than the mean periodic time (which mean is about thirty-three years and a fifth), just that extension of the group which we actually observe would have had time to develop in the fifty-three revolutions that have since taken place.

It is most desirable that everything that it is possible to do shall be done to test this remarkable theory. It seems to be possible to test it, for, owing to the perturbation of their elliptic motion by the planets, the orbits of the meteors suffer an apsidal shift which is easily observed, and which, in fact, retards the date on which the great meteoric showers take place by a considerable amount every century. This is almost wholly owing to the attraction of the great planets *Jupiter* and *Saturn*. *Uranus*

* There is, however, one notable exception. We have reason to suspect that the comet is one of the bodies whose motion was perturbed by the Earth. Accurate observations of the comet should determine whether this is so; and if it prove to be the case, it should be possible further to determine when the catastrophe occurred, by tracing back the comet's course and the Earth's till we come to a time when they were near to one another.

produces a perceptible but trifling effect, and the influence of the Earth and the other planets is insensible. Now it so happens that the periodic time of the meteors is related in a very remarkable way to those of *Jupiter* and *Saturn*, being nearly nine-eighths of the periodic time of *Saturn*, and still more nearly fourteen-fifths of the periodic time of *Jupiter*. Accordingly, in the fifty-three revolutions of the meteors which have taken place since A.D. 126, *Saturn* and they have six times repeated somewhat similar cycles of relative positions, each, moreover, *of a very special character*; and *Jupiter* and they have ten times repeated almost exactly the same cycle of relative positions. Now, where simple numerical relations of this kind subsist, the situation of a meteor along the orbit—viz. whether it is near the head or the tail of the meteoric stream, still more if it be an outlying meteor in front or behind—is likely to have an appreciable effect on the apsidal shift which its orbit suffers. It is, therefore, of great importance to determine whether any such differences between the apsidal shift of meteors variously situated can be observed, in order that the observed amounts may be compared with those calculated on the supposition that Le Verrier's hypothesis is true. If the calculated and observed amounts accord, Le Verrier's hypothesis will be proved; if they do not accord, it will be disproved: in either case we shall know more about the history of the meteors than we do now.

Hence the great importance of this year commencing the task of determining the exact radiant points of different portions of the swarm, and the approximate times of their apparition in our atmosphere, so as to furnish to mathematicians the requisite data for their calculations. In this work it is obvious that eye observations should, as far as possible, be replaced by photographs.*

Galactic Longitude and Latitude of Poles of Binary-Star Orbits.

By Alice Everett.

The data upon which the accompanying table is founded are not satisfactory. In the case of a very few stars there seems little doubt that the orbit determined is substantially correct, and in the case of a few more the elements obtained by different computers show some agreement. These will be recognised in the list by those familiar with the subject. But the greater number of orbits computed seem to be very uncertain.

From the results, such as they are, it does not seem that any decided tendency on the part of the poles of the orbits to favour any special region of the sphere can reasonably be deduced. (See summary appended to tables.)

* A popular account of the discoveries made in connection with the last visit of the November meteors will be found in the Journal of the Royal Dublin Society of 1869 April 3, and in the Proceedings of the Royal Institution of 1879 February 14; and appended to it there is a list of the original memoirs in reference to the advances which were then made.

The stars considered were the following :—

(1) Those for which I could find orbits published since 1890.

(2) Those of period less than 100 years, the orbits of which have not since been re-computed (fifteen in number), given in Mr. Gore's "Catalogue of Binary Stars for which Orbits have been computed" (published in 1890).

The latest orbit has been taken for each star when more than one exists. A few more obviously doubtful or fallacious orbits have been omitted.

I have collected the elements of 73 orbits of 45 stars published since 1890.

The computed galactic longitudes and latitudes of the poles of the orbits are given in the final columns of the table. There are two alternative results for each pole, corresponding to the two possible positions, equally inclined to the line of sight, for the plane of the orbit. The pole whose latitude is the lesser is placed first.

The R.A.'s and Decl.'s of the poles are shown in preceding columns, but here the result is given first for the case where i, the inclination, is assumed positive ; second, where it is assumed negative. Hence the pole entered first in these columns is not necessarily that entered first in the columns containing the galactic coordinates.

The position assumed for the northern pole of the Milky Way was R.A. 190° 31′, Decl. +27° 16′ (1890), as according to Gould, which gives 62° 7′ as the inclination of the central line to the equator and $18^h\ 42^m = 280°\ 31'$ as the R.A. of the ascending node, from which the galactic longitudes are reckoned.

Not knowing that formulæ for finding the R.A. and Decl. of the pole of an orbit had been published (Mr. Marth has since referred me to Encke's article in the *Berliner Astr. Jahrbuch* 1832), I deduced them for myself. A list of R.A.'s and Decl.'s of poles of binary-star orbits was published by Dr. Doberck in 1882 (*Ast. Nach.* 2433), and a sequel to it by Mr. Gore in 1888 in a paper on "The Position of the Planes of Binary Stars" (*Jour. Liv.* A.S. vol. vi.), of the existence of which I was not aware till I had finished my calculations. But nearly all the orbits here considered have been computed in more recent years.

The results were checked by graphic means with the help of a globe, the graphic results generally agreeing with the theoretical to within a degree or two. A globe is, of course, useful in all spherical trigonometrical work in clearing the ideas and showing at sight in what quadrant the angle corresponding to a given trigonometrical function should lie. I bought mine unmounted from the maker in its original simple state before the map and outer coating had been applied, and drew the necessary circles and points of reference upon it. Pencil marks can be written and rubbed out quite well upon the smooth white surface, or sponged off when many accumulate. In default of a spherical sector, spherical angles can be measured as arcs along great circles polar to their apices.

No.	Stars in order of Right Ascension.	R.A. and Decl of star 1890. R.A.			Decl.		Galactic Long. and Lat. of star. Long.	Lat.	Period in Years.	Computer.
		h	m	s	°	′	°	°		
1.	Σ 3062	0	0	30	+57	49	84·5	− 4·5	104·6	See
2.	Σ 2	0	3	15	+79	7	88·1	+16·5	166·2	Glasenapp
3.	η Cassiop.	0	42	27	+57	14	90·1	− 5·5	{ 195·8 208·1	See Lewis
4.	36 Androm.	0	49	5	+23	2	92·1	−39·7	137·5	Lewis
5.	Σ 186	1	50	12	+ 1	18	122·6	−57·1	150·8	Glasenapp
6.	γ Androm.	1	57	8	+41	48	104·7	−18·8	54·8	Burnham
7.	Σ 228	2	7	0	+46	59	104·7	−13·3	88·7	Gore
8.	20 Persei	2	46	46	+37	46	115·6	−18·7	20·8	{ Glasenapp Burnham
9.	40 Eridani	4	10	13	− 7	49	168·5	−37·2	176·2	Glasenapp
10.	OΣ 82	4	16	29	+14	48	147·8	−23·1	158·4	Glasenapp
11.	β 883 = Lal. 9091	4	45	6	+10	53	155·7	−19·9	16·4	Glasenapp
12.	OΣ 149	6	29	34	+29	22	152·3	+10·5	85·9	Glasenapp
13.	Sirius	6	40	18	−16	34	194·6	− 7·9	51·1	Zwiers
14.	Σ 1037	7	5	57	+27	26	157·4	+17·0	15·0	Mädler
15.	9 Argûs	7	46	41	−13	36	199·6	+ 7·6	22·0	See
16.	ζ Cancri	8	5	54	+17	59	172·4	+26·4	59·1	Seeliger
17.	Σ 3121	9	11	22	+29	2	164·8	+43·9	34·0	See
18.	ω Leonis	9	22	34	+ 9	32	190·8	+39·9	116·2	See
19.	φ Ursæ Maj.	9	44	37	+54	35	127·2	+47·9	91·9	Glasenapp
20.	8 Sextantis	9	47	4	− 7	35	213·0	+35·2	93·9	Glasenapp
21.	ξ Ursæ Maj.	11	12	19	+32	9	160·5	+70·0	60·0	See
22.	ι Leonis	11	18	11	+11	8	215·3	+64·5	178·6	Everett
23.	OΣ 234	11	24	53	+41	55	132·1	+68·5	63·5	Gore
24.	OΣ 235	11	26	6	+61	41	105·0	+53·3	94·4	Doberck
25.	γ Centauri	12	35	27	−48	21	268·9	+14·4	88·0	See
26.	γ Virginis	12	36	5	− 0	58	266·8	+61·7	194·0	See
27.	42 Comæ Beren.	13	4	38	+18	7	307·4	+81·8	25·7	{ O. Struve & Doubiago
28.	OΣ 269	13	27	53	+35	29	42·9	+77·3	47·7	Gore
29.	β 612 = B.A.C. 4559	13	34	10	+11	18	310·0	+69·9	30·0	Glasenapp
30.	Σ 1785	13	44	6	+27	32	4·7	+70·2	125·5	Gore
31.	α Centauri	14	32	10	−60	23	283·2	− 0·5	81·2	Roberts—S
32.	Σ 1879	14	40	51	+10	8	334·2	+57·2	146·9	Lewis
33.	OΣ 285	14	41	22	+42	50	40·6	+61·3	76·7	See
34.	ξ Boötis	14	46	19	+19	33	351·6	+60·6	128·0	See
35.	μ^2 Boötis	15	20	20	+37	46	27·8	+55·3	219·4	See
36.	η Cor. Bor.	15	18	40	+30	41	15·2	+55·8	41·6	Doberck
37.	OΣ 298	15	32	3	+40	12	31·5	+52·8	56·7	Celoria
38.	γ Cor. Bor.	15	38	7	+26	39	9·5	+51·0	73·0	See
39.	ξ Scorpii	15	58	19	−11	4	327·9	+28·9	95·9	Doberck
40.	σ Cor. Bor.	16	10	33	+34	8	22·2	+45·2	370·0	See
41.	ζ Herculis	16	37	8	+31	48	19·8	+39·2	35·0	See
42.	β 416 = B.A.C. 5825	17	11	28	−34	52	319·2	+ 1·1	33·0	See
43.	Σ 2173	17	24	45	− 0	59	350·0	+16·7	46·0	See
44.	μ^1 Herculis	17	42	7	+27	47	19·9	+24·6	48·7	Celoria
45.	70 Ophiuchi	17	59	54	+ 2	32	357·4	+10·5	88·4	Schur
46.	99 Herculis	18	2	54	+30	33	24·4	+21·3	54·5	See
47.	ζ Sagitt.	18	55	37	−30	2	334·0	−15·9	18·9	See
48.	γ Cor. Aust.	18	58	59	−37	13	327·2	−19·2	152·7	See
49.	Σ 2525	19	22	4	+27	6	28·5	+ 4·1	138·5	Gore
50.	β Delphini	20	32	33	+14	13	26·3	−16·7	27·7	See
51.	4 Aquarii	20	45	30	− 6	2	9·3	−30·1	120·7	See
52.	δ Equulei	21	9	7	+ 9	34	27·9	−26·7	11·45	See
53.	τ Cygni	21	10	24	+37	35	50·3	− 8·4	36·5	Burnham
54.	*κ Pegasi*	21	39	40	+25	8	45·9	−21·6	11·42	See
55.	*85 Pegasi*	23	56	25	+26	30	77·5	−35·1	24·0	See

A.N. = *Astrono* ichten; M.N. = Montlhly Notices

ource.	R.A. and Decl. of N. Pole of Orbit. I. Inclination positive. R.A.	N. Decl.	II. Inclination negative. R.A.	N. Decl.	Galactic Long. and Lat. of Pole of Orbit. A. Pole of lesser Lat. Long.	Lat.	B. Pole of greater Lat. Long.	Lat.	No.
	°	°	°	°					
292	265	62	30	20	58	+31	294	+39	1.
145	112	24	299	15	202	9	162	20	2.
;5	274	60	42	18					
ol. lv. 19	270	59	42	16	59	28	309	37	3.
ol. li. 462	54	55	169	15	114	0	207	66	4.
.6	326	52	267	51	244	2	45	29	5.
ol. liv. 119	169	53	182	33	116	60	142	81	6.
Cat.	224	62	217	24	66	49	358	66	7.
. A. vol. xii. , June, and Obs. vol. ii.	149	47	177	22	138	52	198	76	8.
357	126	29	170	35	162	34	150	71	9.
193	48	57	254	28	290	1	17	35	10.
119	59	37	261	16	308	11	6	24	11.
Cat.	132	45	73	8	340	20	143	41	12.
336	65	12	325	37	235	12	331	24	13.
Cat.	186	30	227	9	338	51	150	85	14.
297	129	64	194	84	90	33	119	37	15.
Cat.	119	29	123	7	184	23	160	28	16.
9	48	32	20	16	304	21	283	46	17.
311	205	34	266	24	·17	23	32	76	18.
119	203	49	103	36	148	18	69	67	19.
119	165	18	306	33	220	4	196	65	20.
23	243	81	338	23	236	31	81	33	21.
ol. lv. 440	102	41	43	30	143	19	301	25	22.
Cat.	248	65	327	0	63	38	206	40	23.
Cat.	341	58	166	2	255	1	223	55	24.
39	300	18	83	23	331	4	205	9	25.
2	168	22	30	24	292	35	188	69	26.
Cat.	103	10	103	10	172	7	172	7	27.
ol. lii. 550	82	45	70	34	316	7	132	7	28.
A. 466	7	5	222	26	263	58	5	62	29.
l. liii. 333	243	46	181	2	40	45	249	63	30.
75 l. liv. 102	155	3	145	22	210	48	178	48	31.
i. 33	159	62	78	49	128	7	112	49	32.
5	155	70	239	4	342	39	106	43	33.
34	273	4	166	20	0	9	193	66	34.
09	284	36	188	17	35	13	257	79	35.
Cat.	157	35	101	4	177	2	156	60	36.
Cat.	161	17	303	14	203	13	194	61	37.
5	5	62	21	50	268	0	277	12	38.
Cat.	173	7	130	15	179	33	227	64	39.
39	181	44	282	4	4	0	112	72	40.
	183	47	108	5	179	9	104	69	41.
2	108	10	30	48	175	11	283	16	42.
11	340	26	1	24	239	30	259	36	43.
Cat.	175	66	114	31	156	25	100	50	44.
31	314	50	60	46	57	2	296	9	45.
	271	31	271	31	24	21	24	21	46.
	261	34	211	70	25	30	80	46	47.
23	95	4	131	68	353	3	114	37	48.
l. liii. 44	245	77	121	26	163	29	77	34	49.
	245	10	9	3	353	36	268	59	50.
	20	0	63	5	336	31	289	61	51.
90	235	23	212	20	5	50	343	69	52.
s. vol. ii.	17	36	271	15	9	15	276	27	53.
85	83	60	105	48	120	16	137	22	54.
39	63	66	155	24	109	12	178	58	55.

stronomical Journal, A. and A. = *Astronomy and Astro-Physics.*

Summary.

If the sphere be divided into equal-surface zones of galactic latitude, the distribution of the poles of the orbits according to the above results would be as follows:

Zone of Galactic Latitude.	Number of Poles in each Zone. A. When, for each Star, the orbit corresponding to the pole of lesser latitude is taken.	B. When, for each Star, the orbit corresponding to the pole of greater latitude is taken.	Mean of numbers in two preceding columns. $\frac{A+B}{2}$.
$0^\circ-11^\circ$	19	4	$11\frac{1}{2}$
12–23	13	5	9
24–37	13	11	12
37–53	8	11	$9\frac{1}{2}$
53–90	2	24	13

If we consider only stars lying not far from the Milky Way, say, for example, those whose galactic latitude is under 40°, then these numbers become:

Zone of Galactic Latitude.	Number of Poles in each Zone. A.	B.	Mean of numbers in two preceding columns. $\frac{A+B}{2}$.
$0^\circ-11^\circ$	10	2	6
12–23	8	4	6
24–37	11	8	$9\frac{1}{2}$
37–53	5	7	6
53–90	1	14	$7\frac{1}{2}$

Kgl. Astrophysikalisches Observatorium zu Potsdam: 1896 *June.*

On the Corrections to the Right Ascensions of Stars derived from Observations of the Sun made at Greenwich during the years 1836–1895. By W. G. Thackeray.

If a comparison be made between the values of the proper motions in right ascension for the fundamental stars as given by Professor Newcomb in his standard right ascensions, and by Dr. Auwers from his re-reduction of Bradley's observations, it will be found that Professor Newcomb's proper motions are on the average nearly $^s\!\cdot001$ larger than those given by Dr. Auwers. It would therefore seem that the epoch correction of one or other

of these systems of right ascensions must be in error, as they both used Struve's precession.

Professor Newcomb in *A. J.* No. 359, in a paper "On the Value of the Precessional Constant," has shown that, if Δa be assumed to be the correction to the centennial motion of the equinox in R.A. as determined by Auwers Bradley in 1755 and by Pulkova in 1855, a comparison with 97 time stars of the American ephemeris, taking as the basis of comparison his own system of right ascensions as found in the Catalogue of vol. i. of the *Astronomical Papers*, and reproduced in the American ephemeris for the years 1881–1899 gives—

$$\Delta a = +0^{s}\cdot120.$$

Now the Auwers-Bradley's proper motions and the Struve-Peters's value of precession and the places of the stars in the Greenwich Five-Year Catalogue, 1890, constitute the basis of the present Greenwich clock-star lists, and this paper discusses the adoption of this system as a standard and deduces the correction given by the observations of the Sun for the years 1836–1895, with the result that referred the centennial variation $= +0^{s}\cdot132$ to 1880.

From 1836–1852 the clock-star list contained 62 stars, which was increased by the addition of some 90 stars in 1853 to about 150 stars. Further small additions were made from time to time, till in 1859 the list comprised some 190 stars, and at the present time the number of stars has increased to 210.

In order to obtain the necessary correction to the adopted clock-star list places as given in the Introductions to the several volumes of Greenwich observations, the Five-Year Catalogue place of each clock-star has been reduced with Auwers' proper motions and Struve's precession for every year from 1836–1848 and compared with the adopted clock-star place for the year, and the corresponding corrections thus found have been multiplied by weights proportional to the number of observations of each star made in each year, and the sum of all these products divided by the number of the weights has been assumed to be the general correction to the clock-star system in use for each of these years, and therefore the general corrections to the observations of the Sun for that year.

After the year 1848, when the system of making the clock-star list depend on a definite catalogue place was inaugurated, it has been assumed that the mean correction given by all the clock-stars by direct comparison with the Five-Year Catalogue, 1890, reduced to the various epochs of the different catalogues upon which the different clock-star lists depend, constituted the proper correction to be applied to the year's observations as long as the same Catalogue was in use. The legitimacy of this assumption has been verified by finding the actual corrections to the clock errors on each day when the Sun was observed during

the four years 1836, 1841, 1843, and 1846 (chosen at random), deducing the actual correction to the tabular right ascension and the ecliptic north polar distance, and inserting the corrections in the corresponding equations of the discussion of the position of the ecliptic as given in the volume of Greenwich observations.

The following table gives the corrections to the tabular errors of right ascension of the Sun and the corresponding corrections to the ecliptic north polar distance for each month of the four above-named years with the weights used in the equations for the discussion of the position of the ecliptic.

TABLE I.

Corrections to tabular errors of the Sun in right ascension and ecliptic north polar distance to refer the observation of the Sun to a standard system of clock-stars based on the Greenwich Five Year Catalogue, 1890, Auwers-Bradley's proper motions and Struve-Peters precession.

Month.	1836			1841			1843			1846		
	Corr. to Tab. Error of Sun in R.A.	Corr. to E.N.P.D.	Weight.	Corr. to Tab. Error of Sun in R.A.	Corr. to E.N.P.D.	Weight.	Corr. to Tab. Error of Sun in R.A.	Corr. to E.N.P.D.	Weight.	Corr. to Tab. Error of Sun in R.A.	Corr. to E.N.P.D.	Weight.
	s	″		s	″		s	″		s	″	
Jan.	+·036	+·106	12	·000	·000	7	−·095	−·273	7	−·047	−·114	8
Feb.	+·042	+·194	12	+·007	+·029	8	−·082	−·448	11	−·058	−·288	9
Mar.	+·088	+·531	6	+·016	+·096	13	−·052	−·310	13	−·028	−·179	11
Apr.	+·066	+·367	5	+·030	+·159	9	−·072	−·366	12	−·021	−·107	8
May	+·021	+·067	14	+·003	+·010	10	−·109	−·317	10	−·065	−·232	6
June	+·012	+·003	11	+·018	+·014	9	−·073	+·036	9	−·060	−·057	13
July	+·013	−·021	12	+·013	−·040	6	−·086	+·248	7	−·067	+·193	12
Aug.	−·011	+·046	13	·000	·000	12	−·096	+·455	10	−·075	+·425	9
Sept.	−·003	·000	5	+·005	−·030	10	−·103	+·604	14	−·083	+·477	7
Oct.	+·043	−·218	9	−·013	+·063	9	−·096	+·537	15	−·059	+·333	6
Nov.	−·008	+·037	14	−·002	+·007	9	−·100	+·380	9	−·062	+·211	10
Dec.	+·014	−·008	7	−·010	+·005	10	−·108	+·179	7	−·075	+·024	11

Let Δx, Δy, be the corrections to the values of x and y previously deduced, then the corresponding equations from the discussions of the position of the ecliptic in the several volumes of Greenwich observations give for—

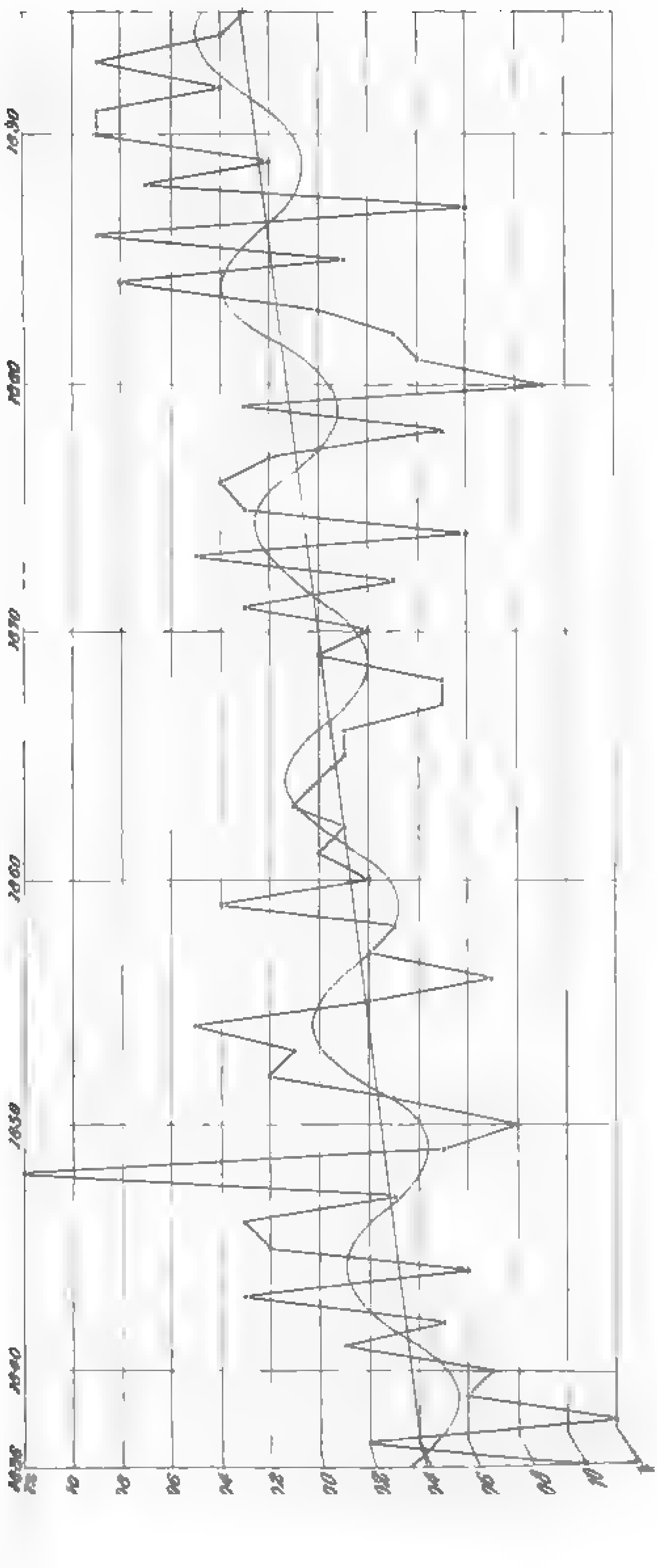
$$1836 \quad \left\{\begin{aligned} 71{\cdot}12\,\Delta x + 7{\cdot}64\,\Delta y &= +10{\cdot}726'' \\ 9{\cdot}66\,\Delta x - 85{\cdot}26\,\Delta y &= +\ 2{\cdot}143 \end{aligned}\right\} \quad \text{whence } \Delta x = +0{\cdot}15''$$

$$1841 \quad \left\{\begin{aligned} 73{\cdot}02\,\Delta x + 14{\cdot}20\,\Delta y &= +\ 2{\cdot}997 \\ 14{\cdot}31\,\Delta x - 69{\cdot}28\,\Delta y &= +\ 1{\cdot}043 \end{aligned}\right\} \quad \text{whence } \Delta x = +0{\cdot}04$$

$$1843 \quad \left\{\begin{aligned} 88{\cdot}33\,\Delta x + 18{\cdot}07\,\Delta y &= -43{\cdot}797 \\ 14{\cdot}77\,\Delta x - 67{\cdot}81\,\Delta y &= -\ 3{\cdot}845 \end{aligned}\right\} \quad \text{whence } \Delta x = -0{\cdot}49$$

$$1846 \quad \left\{\begin{aligned} 66{\cdot}26\,\Delta x + 14{\cdot}13\,\Delta y &= -22{\cdot}314 \\ 17{\cdot}16\,\Delta x - 71{\cdot}12\,\Delta y &= -\ 7{\cdot}591 \end{aligned}\right\} \quad \text{when } \Delta x = -0{\cdot}33.$$

Corrections in Right Ascensions of Clock Stars referred to a uniform system from observations of the Sun, 1836–1895.



Dividing each of these quantities by $15 \sin 23^\circ 28'$ we get the following corrections to the right ascension of the stars:

Years	1836.	1841.	1843.	1846.
(1)	$+^s\cdot025$	$+^s\cdot007$	$-^s\cdot081$	$-^s\cdot055$

the values previously adopted by weighting the corrections for each star proportionally to the number of observations made in each year was

(2)	$+^s\cdot020$	$+^s\cdot008$	$-^s\cdot076$	$-^s\cdot060$

by taking the simple mean of all the corrections to all the clock-stars, and virtually assuming that the clock errors for the observations of the Sun are well distributed over the whole clock-star list in the course of the year, these quantities would be

(3)	$+^s\cdot026$	$+^s\cdot012$	$-^s\cdot079$	$-^s\cdot060$

It would thus appear that the observations of the clock stars upon which the Sun observations in the course of a year depend seem to be well distributed over the whole list, or that the errors of the individual clock errors are of an accidental character, and in the main well determined. In any case it does not appear that the method (2) or (3) of finding the correction to the adopted results of the Sun observations can introduce any sensible error, especially as we are adopting in the final results only two places of decimals, and also considering the large accidental errors evidently existing in the quantities themselves.

The chronograph was brought into use during the year 1854.

TABLE II.

Table of adopted corrections to reduce the adopted Clock-Star Lists, 1836–1895, *to the Right Ascensions of the Five-Year Catalogue,* 1890.

Year.	Corr. (s)	Year.	Corr. (s)
1836	$-\cdot020$	1846	$+\cdot060$
1837	$-\cdot013$	1847	$+\cdot078$
1838	$-\cdot015$	1848	$+\cdot078$
1839	$-\cdot001$	1849–1855	$+\cdot011$
1840	$-\cdot000$	1856–1861	$+\cdot002$
1841	$-\cdot008$	1862–1869	$+\cdot005$
1842	$-\cdot001$	1870–1877	$+\cdot013$
1843	$+\cdot076$	1878–1888	$\cdot000$
1844	$+\cdot083$	1889–1895	$\cdot000$
1845	$+\cdot089$	...	...

These quantities with sign changed are directly applicable (see *M. N.* liv. p. 417) to the quantities given in the introductions to the several catalogues as corrections to the right ascensions of clock-stars from discussions of the position of the ecliptic, and these quantities thus corrected are given in the following table.

For the years 1836–1863 the places of the Sun were computed from Carlini's Tables; from 1865–1895 from those of Le Verrier :—

TABLE III.

Table of corrections to a system of Right Ascensions of Clock-Stars depending on the position of the Five-Year Catalogue, 1890, from observations of the Sun for the years 1836–1895.

Year.	Corr. s	Year.	Corr. s	Year.	Corr. s	Year.	Corr. s
1836	−0·11	1851	−0·03	1866	−0·01	1881	−0·04
1837	− ·03	1852	+ ·02	1867	− ·05	1882	− ·03
1838*	− ·12	1853	+ ·01	1868	− ·05	1883	·00
1839	− ·07	1854	+ ·05	1869	·00	1884	+ ·08
1840	− ·09	1855	− ·02	1870	− ·02	1885	− ·01
1841	− ·01	1856	− ·07	1871	+ ·03	1886	+ ·09
1842	− ·05	1857	− ·02	1872	− ·03	1887	− ·06
1843	+ ·03	1858	− ·03	1873	+ ·05	1888	+ ·07
1844	− ·07	1859	+ ·04	1874	− ·06	1889	+ ·02
1845	+ ·00	1860	− ·02	1875	+ ·03	1890	+ ·09
1846	+ ·03	1861	·00	1876	+ ·04	1891	+ ·09
1847	− ·04	1862	− ·01	1877	+ ·02	1892	+ ·04
1848	+ ·11	1863	+ ·01	1878	− ·05	1893	+ ·09
1849	− ·05	1864	·00	1879	+ ·03	1894	+ ·04
1850	− ·08	1865	− ·01	1880	− ·09	1895	+ ·03

The mean of these corrections is

$$-0^{s}{\cdot}005 \pm 0{\cdot}0047,$$

and the probable error of a single determination is

$$\pm 0^{s}{\cdot}035.$$

The true value of this correction being of the form

$$x + y\mathrm{T} = \text{annual correction},$$

where T is the fraction of a century from the adopted epoch 1880, the solution of the sixty resulting equations by the method of least squares gives the following normal equations :

$$60\,x - 8{\cdot}70y = -0^{s}{\cdot}29$$
$$-8{\cdot}70\,x + 3{\cdot}07y = +0{\cdot}30,$$

whence

$$x = +0^{s}{\cdot}015 \qquad y = +0^{s}{\cdot}132.$$

The quantities in Table III., arranged in series of ten years, show as follows:—

1836.	1837.	1838.	1839.	1840.	1841.	1842.	1843.	1844.	1845.
$-^s\cdot005$	$-^s\cdot030$	$-^s\cdot012$*	$-^s\cdot005$	$-^s\cdot035$	$+^s\cdot007$	$-^s\cdot008$	$+^s\cdot030$	$+^s\cdot008$	$+\cdot003$

* Excluding the result for 1848, which is somewhat anomalous, the result would be $-^s\cdot030$.

This apparent period may be purely accidental, but a correction may be fairly represented by the expression

$$+0^s\cdot02 \cos (T-1844)\ 36^\circ.$$

As the accidental errors existing in the correction to the right ascensions of the clock-stars derived from the discussions of the position of the ecliptic appear to be large, it would seem inexpedient to refer catalogues extending over a short period of time directly to the corresponding observations of the Sun in preference to basing the right ascensions on a well-determined system of clock-stars.

As an instance of the uncertainty of the actual value of this correction, the 1840 and 1845 Greenwich Catalogues afford instructive examples, for in the Introduction it is shown that after the clock-stars have been all reduced to the same system, the correction for epoch for the years 1836–41 is $-0^s\cdot110$, and for the years 1842–48 is $-0^s\cdot043$.

On the Proper Motion of B.D. + 25°, No. 2874.
By Walter W. Bryant.

This star is a wide companion of *c Boötis*, which appears in most catalogues with a well-determined P.M. of $+0^s\cdot0116$ in R.A. and $+0''\cdot191$ in N.P.D.

Baron d'Engelhardt measured this among his Bradley's wide pairs, and from his observations, made in 1887 and 1889, suspected that the faint star had also a P.M. Finding a meridian observation of the star in B.D. (vol. vi.), which confirmed this view, he wrote to Professor Schönfeld, who assured him that he had no reason to suspect the accuracy of the Bonn observation.

Combining this with his own observations, the Baron obtained for this star a P.M. of $-0^s\cdot0642$ in R.A. and $-0''\cdot408$ in N.P.D. He notes the magnitude as 9·5 (fainter than 9·2 given in B.D. But being apparently desirous to risk nothing on the accuracy of a single meridian observation, he continued his measures in 1893 and 1895, and from his own sets (11 measures in all) he obtained a revised value of P.M. in R.A. $-0^s\cdot0666$, and in N.P.D. $-0''\cdot631$.

It will be noted that the agreement in R.A. is fair, but in N.P.D. very poor.

After a fruitless search through many catalogues and volumes of observations I discovered a single observation of the star made at Vienna in 1836, over two wires only in R.A. and without any N.P.D., which, by differentiating from the observation of *c Boötis* taken just before it, gave a difference of R.A. of $18^s{\cdot}8 \pm 0^s{\cdot}2$, from which the R.A. of the star in question is half a second too great compared with the later observations.

On account of the suspected large P.M. the star was entered in the Greenwich Working Catalogue, and three observations have been secured this year, giving the place of the star.

	R.A. 1896·0.	N.P.D. 1896·0.
		° ′ ″
Apr. 22	15 2 57·56	64 40 41·13
May 11	15 2 57·53	64 40 42·93
14	15 2 57·43	64 40 43·43

(reduced without P.M. to 1896·0).

Combined with the Bonn observation these give—

$$\text{P.M.} -0^s{\cdot}0632 \text{ in R.A. and } -0''{\cdot}479 \text{ in N.P.D.,}$$

thus confirming the smaller values obtained before from the Bonn observation, and perhaps casting doubts on its accuracy.

But though the accuracy of single meridian observations may be very well despised there will be noted a peculiar run in the three Greenwich observations. Now a star with a P.M. amounting to over 1″ of arc may be very readily suspected of having an appreciable parallax.

The above star is in opposition on May 8, so that if it have any parallax there would be a great difference between observations a month before and a month after this date, amounting in R.A. to the whole of the semi-annual parallax.

Also being some 42° north of the ecliptic, its parallax in N.P.D. will make that element a minimum about opposition.

So the Greenwich R.A.'s as they diminish through opposition give some evidence of parallax in R.A., while the N.P.D.'s, though they do not indicate any minimum, yet are increasing after opposition, as would be expected on the above hypothesis.

Again, Baron d'Engelhardt's observations, which indicate a smaller R.A. than the Greenwich ones, are none of them earlier than the end of June, when the parallax in R.A. would tend to make it smaller, while the progressive change due to it is then so small that it would easily escape notice. In N.P.D. it would be noticeable at that time (though of course never so much so as in the R.A. before and after opposition), and, curiously enough, Baron d'Engelhardt's N.P.D. observations do not give so near an agreement as his R.A.'s, the observations of 1889, which were

made in July, standing out in both elements from those of the other three years, made towards the end of June.

It seems quite possible, therefore, that this star will repay observations made east of the meridian in the winter, and a very few measures would suffice to show whether the investigation were really worth pursuing.

The distance of the star from *c Boötis* is roughly 13½ seconds following and nearly 3′ north.

Occultations of certain Stars in Præsepe by the Moon on 1896 *October* 1, *visible at Greenwich.*

(*Communicated by the Superintendent of the "Nautical Almanac."*)

The following table gives the particulars of the Occultations of the brighter stars in Præsepe on October 1 next, as visible at Greenwich. The places of the stars have been taken from Schur's *Die Oerter der hellern Sterne der Præsepe.*

If it should be found possible to observe any fainter stars in Schur's list than those included in the following table, the circumstances of their occultation can easily be deduced graphically, with sufficient accuracy for the purpose of identification, from the data of the table.

The time of Sun rise at Greenwich is $18^h\ 4^m$.

Occultations visible at Greenwich, 1896 *October* 1.

The Angles are reckoned from the North Point and Vertex of the Moon's limb towards the East.

Star's Name	Schur's No.	Mag. (B.D.)	Disappearance. G.M.T.	North	Vertex.	Reappearance. G.M.T.	North	Vertex.
			h m	°	°	h m	°	°
38 Cancri	No. 15	7·0	16 13	79	118	17 14	321	355
BD + 20° 2150	No. 17	7·2	16 24	125	165	17 32	273	305
BD + 20° 2166	No. 27	7·3	16 34	91	129	17 41	310	341
ε Cancri	No. 31	7·2	16 40	115	153	17 52	286	315
42 Cancri	No. 34	7·1	16 46	73	110	17 44	329	359
BD + 20° 2175	No. 37	7·7	16 53	99	136	18 4	303	330
BD + 19° 2069	No. 26	7·0	17 0	163	199	17 43	237	268
BD + 20° 2185	No. 43	7·5	17 46*	22	53			

Nautical Almanac Office,
1896 *June* 6.

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* A near approach.

Note on a Possible Eclipse of Jupiter's Second Satellite by the Shadow of the Third 1896 March 30. By A. C. D. Crommelin.

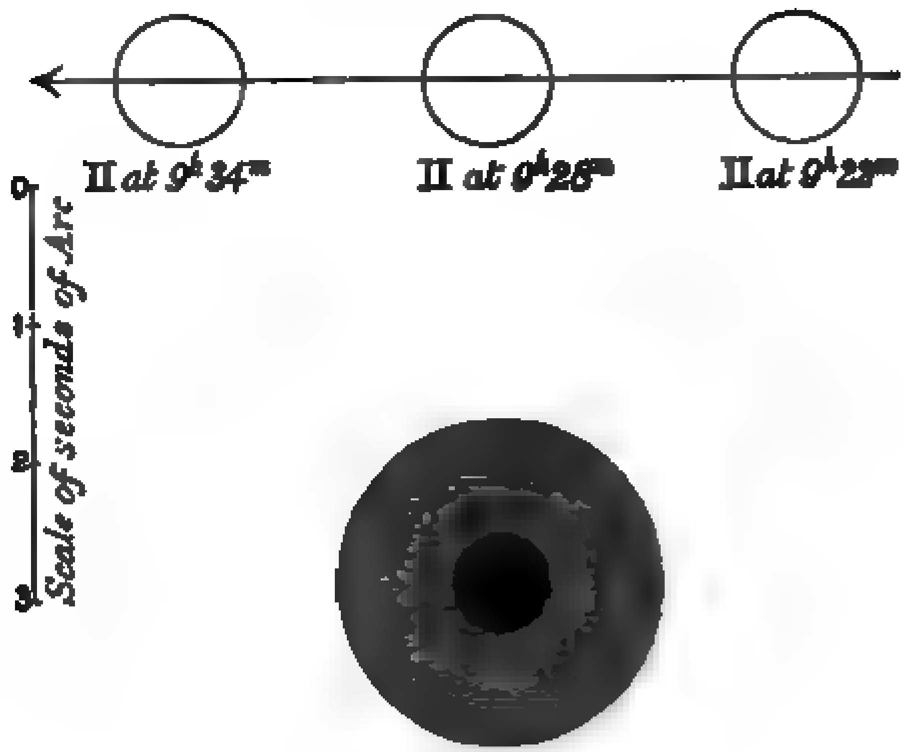
The April number of the "Journal of the Astronomical Society of Wales" contains the following communication from Mr. Fred Jackson, of Stoke-on-Trent: "A curious extinction of Satellite II. took place for a few seconds March 30, about $9^h\ 10^m$. The other satellites appeared as usual, but II. was very indistinct before its strange disappearance, and of a dirty yellow colour." This description suggested an eclipse by the shadow of one of the other satellites, and on examination I found that the shadow of III. was in close proximity to II. at the time named. In reply to my request for further particulars, Mr. Jackson forwarded the following additional details, which he permits me to reproduce:—

"On March 30, about $9^h\ 20^m$ (the time $9^h\ 10^m$ given in the 'Journal of the Astronomical Society of Wales' is erroneous), observing with a 5-inch reflector, power 110, I noticed that Satellite II. was very faint and indistinct. It was very much smaller than the others, and required quite an effort to see it. I happened to turn from the telescope for a minute or so, and when I looked again I could not see the satellite for a few seconds, the other satellites being visible at the first glance. When I caught sight of II. again it was small and ill-defined, and appeared as though it was struggling through something. It grew brighter shortly afterwards, but not as bright as I have seen it on other occasions, even in the immediate vicinity of the primary. I left off observing Jupiter shortly afterwards, and did not see the occultation of II., which took place at $9^h\ 57^m$. The night was not a very favourable one for observation, only first and second magnitude stars being visible to the naked eye. The details on the surface of Jupiter were not sufficiently well-defined to permit of making a drawing."

Mr. Jackson states that he has been observing for some years, and has had a fair amount of experience.

Mr. Marth kindly communicated to me the following particulars of the heliocentric positions of the satellites:—

True time.	Time corrected for light passage to Earth 41 mins.	Relative heliocentric positions of II. and III. x_2-x_3.	y_2-y_3.
d h m	h m	″	″
Mar. 30 8 20	9 1	− 9·89	+ 3·60
8 50	9 31	+ 1·20	+ 3·55
9 20	10 1	+ 12·36	+ 3·50



Shadow and Penumbra of III.

Diagram illustrating the Conjunction of Satellite II with the Shadow of III.

The diagram shows the projection of the shadow of III. on a plane through II., normal to the radius vector, and the position of II. relatively to the shadow at $9^h\ 22^m$, $9^h\ 28^m$, and $9^h\ 34^m$. (These times have been corrected for the time of light passage to the Earth.) The assumed diameters of the satellites are III. 3,560 miles, and II. 2,200 miles. It will be seen that an error of $2''$ in the difference of the latitudes of the satellites, as given by the Tables, would suffice to bring II. partially within the penumbra of III. Such an error is larger than we should expect, but perhaps not wholly inadmissible. I am, however, by no means confident that an eclipse actually occurred; though, if not, the almost perfect agreement in time between this observation and conjunction with the shadow would be a curious coincidence. But the possibility of such a rare phenomenon having taken place makes it advisable to call attention to the above observation. According to Webb's "Celestial Objects for Common Telescopes" (4th edition, p. 164), there is one case on record of the eclipse of one satellite by the shadow of another; the reference, however, is not given, and I have not been able to identify it. It is scarcely necessary to point out the great value of undoubted observations of the kind for determining the positions of the orbital planes of the satellites.

7 Vanbrugh Park Road, Blackheath, S.E.:
1896 *June* 10.

Measures of the Polar Diameter and of the Principal Belts, and of Two Dark Spots on Jupiter, and of the Satellites and their Shadows in Transit, made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Apparition of 1895–96. By Joseph Gledhill.

Measures of the Polar Diameter.

The following results were obtained in four ways—A, by direct measures of the polar diameter of the apparent disc; B, by measures of the distances of satellites and shadows in transit from the poles of the disc; C, by measures of the distances of dark spots in transit from the two poles; D, by measures of the distances of the principal dark bands from the two poles.

In every case the micrometer was set to the computed position angle of *Jupiter's* equator as given by Mr. Marth.

The instrument used was the $9\frac{1}{3}$-inch Cooke equatorial refractor, with the parallel-wire micrometer by Simms, power 282.

A.

Under *a* is given the number of measures; under *b* the diameter; *m* measured, M Mr. Marth's value (both to the nearest tenth of a second); and under *c* the difference between *m* and M.

		b		*c*			*b*		*c*
1896.	*a*	*m*	M			*a*	*m*	M	
		″	″	″			″	″	″
Feb. 26	12	42·3	42·0	+0·3	Apr. 21	7	35·9	35·8	+0·1
Apr. 11	6	36·6	36·9	−0·3		6	36·1	35·8	+0·3
12	5	36·8	36·8	0·0	22	5	35·8	35·7	+0·1
13	8	36·4	36·7	−0·3	23	10	35·6	35·6	0·0
15	9	36·3	36·5	−0·2	24	5	35·6	35·5	+0·1
16	6	36·1	36·3	−0·2	26	6	34·9	35·3	−0·4
18	7	36·1	36·1	0·0	28	7	35·1	35·0	+0·1
20	5	36·0	35·9	+0·1	29	5	34·7	34·9	−0·2

The mean difference, regardless of sign, is nearly 0″·2.

B.

Feb. 23	39	43·0	42·2	+0·8	Apr. 3	2	38·1	37·8	+0·3
Mar. 18	9	40·0	39·7	+0·3	6	20	37·7	37·5	+0·2
19	2	39·5	39·6	−0·1	20	4	36·6	35·9	+0·7

The mean difference is 0″·4.

C.

1896.	a	b m	b M	c		a	b m	b M	c
		″	″	″			″	″	″
Feb. 26	3	43·0	42·0	+1·0	Mar. 18	2	39·7	39·7	0·0
	5	42·6	42·0	+0·6	23	6	38·9	39·2	−0·3
Mar. 9	6	41·4	40·8	+0·6	30	2	37·8	38·3	−0·5
15	4	39·4	40·1	−0·7	Apr. 11	4	36·6	36·9	−0·3

The mean difference is 0″·5.

D.

Mar. 9	4	40·2	40·8	−0·6	Apr. 18	6	36·4	36·1	+0·3
12	8	39·8	40·4	−0·6	20	6	36·4	35·9	+0·5
23	7	39·2	39·2	0·0	21	6	36·1	35·8	+0·3
30	3	38·3	38·3	0·0	22	6	35·9	35·7	+0·2
Apr. 3	4	37·8	37·8	0·0	23	6	35·6	35·6	0·0
9	6	37·5	37·1	+0·4	24	7	35·6	35·5	+0·1
10	5	37·6	37·0	+0·6	26	5	35·2	35·3	−0·1
11	5	36·6	36·9	−0·3	28	5	35·1	35·0	+0·1
12	6	36·5	36·8	−0·3	29	4	34·8	34·9	−0·1
13	6	37·1	36·7	+0·4	May 6	5	34·1	34·2	−0·1
15	6	36·6	36·5	+0·1					

The mean difference is 0″·24.

The computed values are for noon of each day, and are taken from Mr. Marth's ephemerides.

With regard to the atmospheric conditions prevailing when the above observations were made, it should be said that on no occasion were they really good, and rarely fairly good. It is only when mist or thin cloud prevails that steady images are obtained here.

Measures of the Position Angle of the North and South Edges of the Bright Equatorial Zone of Jupiter.

The strongly-marked double dark band just south of the equator was used in the earlier measures, and the narrow dark band just north of the equator in the later measures. After adjusting the parallel-wire micrometer on a bright and a fainter star near the meridian, the position webs were placed parallel to one of the belts just named.

In column *a* are given the means of from three to five measures; in column *b*, the position angle of the equator, from Mr. Marth's ephemerides. Power 282 was always used.

1896.	a	b		a	b
	°	°		°	°
Mar. 23	103·2	103·7	Apr. 18	104·2	104·0
Apr. 3	103·3	103·7	23	104·0	104·2
9	103·9	103·8	24	104·3	104·2
11	103·7	103·8	26	104·1	104·3
13	103·8	103·9	29	105·1	104·4
15	104·1	103·9	May 11	105·0	104·9
16	104·3	104·0			

These bands, therefore, are sensibly parallel to *Jupiter's* equator.

Measures of the Position, &c., of the Principal Belts.

The salient features lately visible on the planet *Jupiter* are perhaps best described by using the terminology adopted by the *British Astronomical Association*, viz. the North Temperate Band, the North Equatorial Belt, the South Equatorial Belt, the South Temperate Band; these are the dark bands or belts. The bright zones are called the North Tropical Zone, the Equatorial Zone, and the South Tropical Zone. There are other fainter bands and narrower zones, but of these nothing will be said in this paper.

It was with the object of determining the latitudes of the principal belts that the measures about to be given were made. And it soon became obvious that to do this with great accuracy careful work on really good nights would be required. The present paper is the result of an attempt to do this under the best observing conditions experienced here since January last. And it may at once be said that the definition and steadiness of the image were never of the best quality.

The measures were all made with the $9\frac{1}{3}$-inch Cooke equatorial refractor and the Simms parallel-wire micrometer; power, 282.

No attempt was made to *measure* the width of the narrow bands; the webs were set apart to the estimated width, and then brought near the bands for comparison.

On trial it was found that Mr. Marth's position angle of the polar axis of *Jupiter* plus 90° brought the adjusted web of the micrometer into a position parallel to the equatorial belts. Hence the method adopted was to set the position circle to its zero reading, clamp it, and then adjust the micrometer by a bright and a faint star near the meridian; then, lastly, move the vernier to the reading for the Jovian equator, and again clamp the position circle.

The value of one revolution of the micrometer screw is $13''{\cdot}837$; one division of the divided head $=0''{\cdot}138$. One web was placed on the edge or middle of a band, the other just on the north limb of *Jupiter*; the web was then carried to the other

side of the fixed web, and the measure repeated. Similarly for the south limb.

The Polar Shading.

The dusky regions near the poles were not critically examined, but taken as a whole, and the distances of the north and south edges from the south and north poles of the disc were measured. No doubt the extent of this shaded part of the disc is not quite the same in all longitudes, and this fact may be indicated by the differences in the few results here given.

1896.	d	h			
Feb.	12	11	width of N. shading	$=6''.4$;	of S. shading $=7''.3$
	26		" " "	7·0;	" " 7·0
Mar.	9		" " "	7·7;	
Apr.	24		" " "	6·6;	" " 6·6

These are reduced to $\Delta = 5.20$.

The North Temperate Band.

As an illustration of the kind of accordance obtained from night to night the following extract from the note books is given :—

1896	h			
April 10	7½	$+8''.0$	$+7''.9$	$+0''.3$
11	8	7·4	7·3	−0·3
12	8½	7·4	7·3	−0·3
13	8	7·9	7·8	+0·2
15	8	7·6	7·5	−0·1
16	8	7·4	7·3	−0·3
20	8	+7·9	+8·0	+0·4

where the distance of the middle of the band from the equator is given in the third column; the fourth column gives the distances reduced to $\Delta = 5.20$, and the fifth the differences from the mean of all.

1896			Latitude	
Feb. 26 to Apr. 13	...	$+7''.25$	$+24^\circ.3$	10 nights
Apr. 15 to Apr. 24	...	7·63	25·7	7 "
Apr. 26 to May 10	...	7·36	24·7	5 "

The mean of all $+7''.4$, and $24^\circ.9$. The width of this band varies in different longitudes; it has never been a conspicuous band since 1895 October, and it was often difficult to see distinctly enough for a good measure.

Its breadth ranges from about $1\frac{1}{2}''$ to $2\frac{1}{2}''$, the mean of one set of 5 nights' measures being $2''.3$, and of another similar set $1''.7$.

The North Equatorial Belt.

This is a narrow and comparatively inconspicuous belt in all longitudes, and was seldom well seen. The reduced measures are—

			Width.	
$+2''.2$	$+7^\circ.7$	10 nights		
$+2.5$	$+8.6$	10 ,,	$1''$	5 nights
$+2.6$	$+8.8$	10 ,,	$1''$	5 ,,

The means are $+2''.4$ and $+8^\circ.3$.

The South Equatorial Belt.

This has been the most salient feature of the planet throughout the present apparition, and could be well seen through terrestrial clouds of considerable density. It is double in all longitudes if we except the small portion just under the Red Spot, where it becomes single.

The middle of the band :

			Means
$-4''.0$	$-13^\circ.1$	10 nights	$-3''.9$ and $-13^\circ.1$
-3.9	-13.1	10 ,,	

The north edge :

			Means
$-2''.32$	$-8^\circ.2$	9 nights	$-2''.2$ and $-7^\circ.7$
-2.27	-7.8	9 ,,	
-2.1	-7.2	5 ,,	

The south edge :

			Means
$-5''.76$	$-19^\circ.3$	10 nights	$-5''.7$ and $-19^\circ.1$
-5.72	-19.0	10 ,,	

Width of this double band :

$3''.5$	10 nights	Mean $=3''.5$
3.5	10 ,,	
3.5	10 ,,	

At its narrowest part, just under the Red Spot, the width is about $1''$.

The South Temperate Band.

This was not often seen very distinctly.

$-8''.7$	$-29^\circ.4$	10 nights

The North Tropical Zone.

Its width :—

3″·2	5 nights	Mean = 3″·1
3·0	5 „	
3·2	5 „	

The Bright Equatorial Zone.

3″·8	5 nights	Mean = 3″·6
3·6	5 „	
3·3	5 „	

It is possible that some of the discordance in some of the above measures for latitude may arise either from actual differences in latitude of the belt in certain longitudes, or from drift in latitude since the observations began. For a full discussion the longitude of each night's measures would be needed; the longitude was recorded, but it has not been thought necessary to give it. At any rate the question of drift has already become an interesting and important element in the study of the physical features of *Jupiter*. And the following extracts (especially that from the admirable series of measures by Professor Hough) will be read with interest (see the *Annual Reports of the Dearborn Observatory*; also *The Observatory*, vol. iv. p. 325, and the *Astronomische Nachrichten*, vol. cxl. p. 169 and p. 273) :—

	1811	1876	1880
South pole to 1st belt ...	13″·60	15″·54	15″·94
„ 2nd „ ...	20·60	19·71	19·34
„ 3rd „ ...	23·67	22·57	24·55
„ 4th „ ...	29·12	28·96	31·86

The measures under 1811 were by Arago, in 1810–13; those in 1876 and 1880 by Russell. Latitude of first belt is −36° to −38°; of second, −18°; of third, +18°; of fourth, +36° to +38°.

Dr. L. de Ball has, for 1884–5, the following results :—

N.P.D. of middle of great south belt	21″·9
„ „ north „	14·0
S.P.D. „ south „	15·1
„ „ north „	22·0

Professor Hough's measures are, for the north and south edges of the equatorial zone—*

	1879	1880	1881	1882	1883	1884	1890
	"	"	"	"	"	"	"
North edge	+2·59	2·33	2·16	2·44	2·58	4·95	4·52
South edge	−4·18	4·71	4·75	6·36	5·80	4·69	
Width	6·77	7·04	6·91	8·80	9·30	10·03	9·49

Lastly, the following latitudes, by Dr. E. Lamp, have just appeared in the *Astronomische Nachrichten* (vol. cxl. p. 169); they are for 1896 March :—

North edge	of north	temperature band	...	+ 25°·9
South	„	„	...	+ 21·7
North	„	equatorial band	...	+ 6·0
South	„	„	...	+ 2·0
North	„ south	„	...	− 5·0
South	„	„	...	− 16·8
North	„	temperate band	...	− 28·5
South	„	„	...	− 34·1

Observations of Two Dark Spots Seen on One of the Bright Zones of Jupiter.

In the early morning hours of 1895 October 30 an elongated dark spot was noticed near the north edge of the north equatorial belt and in the bright north tropical zone. It was quite detached from the belt; its length was about $2\frac{1}{2}''$, breadth about $1\frac{1}{4}''$, with the longer axis parallel to the dark belt. At the time of its transit across the central meridian its Jovicentric longitude was about 222°. It passed the central meridian of the disc about $3^h\ 47^m$ before Mr. Marth's zero meridian, and is the *grey spot* of the following notes.

Another spot of about the same size and shape, but much darker, was not noticed here until 1896 January 28; it was in longitude 269°, passed the central meridian about $2\frac{1}{2}^h$ before the zero meridian in the same latitude as the grey spot, and is the *dark spot* of the following notes.

A few measures of the length of the *dark spot* were made, but, as the earlier ones differ so much from those made in April of this year, I suspect the accuracy of the former; however, here they are :—1895 November 13, $2''\cdot4$; 1896 January 30, $2''\cdot5$; February 23, $1''\pm$; March 9, $1''\cdot2$ (width, $\frac{1}{2}''+$); April 23, $1''\cdot5$; April 20, $1''\cdot7$; April 28, $1''\cdot4$ (width, $1''$).

* By *Equatorial Zone* Professor Hough means the north equatorial belt, the south equatorial belt, and the bright zone (equatorial) between them. (See *Ast. Nach.* vol. cxl. p. 273.)

The following tables give a complete list of the transits of the spots :—

The Grey Spot.

G.M.T. of Transit.		λ		G.M.T. of Transit.		λ	
1895 d	h m	°		1896. d	h m	°	
Oct. 29	17 5	222·0	Good.	Feb. 9	6 14·5	197·0	Poor.
Nov. 11	12 47	220·0	Good.	12	13 37·5	196·3	Fair.
13	14 23	219·3	Fair.	22	11 49·5	196·0	Poor.
17	7 43	216·5	Good.	23	7 43	195·5	Fair.
18	13 31	218·0	Poor.	25	9 21	195·2	Poor.
30	13 15	218·0	Bad.	Mar. 15	10 3	195·9	Poor.
Dec. 19	13 49·5	212·0	Good.	18	7 33	196·0	Poor.
1896.				Apr. 18	7 55·5	184·5	Fair.
Jan. 28	6 35	204·9	Poor.	20	9 27	180·1	Fair.
Feb. 3	11 29	204·8	Bad.	25	8 39	181·8	Good.
6	8 50·5	200·3	Poor.	30	7 50	182·5	Good.

The first column gives the G.M.T. of the spot's transit over the apparent central meridian ; the second gives the Jovicentric longitude of the spot at central transit ; the last gives an estimate of the quality of the observation at the time.

The Dark Spot.

G.M.T. of Transit.		λ		G.M.T. of Transit.		λ	
1896. d	h m	°		1896. d	h m	°	
Jan. 28	8 21	268·9	Poor.	Mar. 18	9 20	260·6	Fair.
30	9 58	268·3	Fair.	23	8 22	258·5	Bad.
Feb. 6	10 41	367·0	Poor.	25	9 57	254·3	Poor.
9	8 6	264·5	Poor.	28	7 30	256·1	Poor.
11	9 40	262·0	Fair.	30	9 9	256·3	Fair.
14	7 16	266·0	Poor.	Apr. 9	7 23	254·0	Fair.
23	9 35	263·1	Fair.	11	8 58	252·0	Poor.
24	5 30	265·4	Poor.	16	8 6	250·7	Fair.
26	7 6	263·4	Fair.	18	9 45·5	251·9	Fair.
Mar. 1	10 15	259·4	Fair.	20	11 29	253·8	Fair.
4	7 48	261·5	Fair.	23	8 54	250·6	Good.
6	9 25	260·6	Poor.	28	8 3	250·1	Fair.
8	11 5	261·0	Poor.	30	9 43	250·7	Fair.
9	6 55	260·7	Fair.	May 5	8 50·5	249·6	Good.
16	7 43	261·6	Poor.	10	8 0	249·2	Good

Taking observations not less than about ten days apart the following series of ten is obtained :—

The Dark Spot.

Observed G.M.T. of Transit.				λ	L	Δ	R
1896.	d	h	m	°	°		
Jan.	28	8	21	268·9	123·6	4·30	0
Feb.	14	7	16	266·0	121·9	4·37	41
	26	7	6	263·4	120·3	4·47	70
Mar.	4	7	48	261·5	119·8	4·55	87
	16	7	43	261·6	119·2	4·69	116
	25	9	57	254·3	119·1	4·82	138
Apr.	9	7	23	254·0	119·5	5·07	174
	23	8	54	250·6	120·4	5·28	208
	30	9	43	250·7	121·1	5·39	225
May	10	8	0	249·2	119·8	5·54	249

where λ is the Jovicentric longitude of the spot, L the geocentric longitude of *Jupiter*, Δ the distance of the Earth from *Jupiter*, and R the number of rotations.

A few trials showed that a period of $9^h\ 55^m\ 30^s$ very nearly represented the observations. This was adopted as the assumed period. The observations were then corrected for longitude and aberration, all being reduced to geocentric longitude 125° and to $\Delta = 5{\cdot}20$; and thus the corrected times were obtained.

Putting a for the error of the first aberration, ρ for the correction of the assumed period, T for the corrected time of an observation, and T_0 the corrected interval between any observation and the first, the equations of condition take the form

$$a + N\,(595^m{\cdot}5 + \rho) = T - T_0.$$

N = the number of rotations.

From the ten equations of condition the two normal equations were derived and solved, and the following values resulted :

$$a = -0^m{\cdot}67 \qquad \rho = +0^m{\cdot}05.$$

Hence the period is $9^h\ 55^m\ 33^s$.

With the help of the Greenwich Mean Times when the zero-meridian passed the middle of the illuminated disc (given in Mr. Marth's ephemerides) in the assumed System II., the period of rotation is very readily found when the observed times of transit of the spot are known, and the value thus obtained is identical with that just given.

The Grey Spot.

1895. d	h m	λ (°)	L (°)	Δ	R
Oct. 29	17 5	222·0	128·0	5·2	0
Nov. 11	12 47	220·0	128·8	5·0	31
Dec. 19	13 49·5	212·0	128·2	4·5	123
1896. Jan. 28	6 35	205·0	123·6	4·3	219
Feb. 25	9 21	195·0	120·4	4·5	287
Mar. 15	10 3	196·0	119·3	4·7	333
Apr. 18	7 55·5	184·0	119·7	5·2	415
30	7 50	182·0	121·1	5·4	444

Correcting as before, reducing to L = 130° and Δ = 5·20, forming the equations of condition, and solving the two normal equations, the period is found to be $9^{h}\ 55^{m}\ 32^{s}$.

The Latitude of the Spots.

The distance from the centre of the dark and grey spots to the north and south poles was measured on every fine night between 1895 October 29 and 1896 May 10, the micrometer being set to the computed position angle of *Jupiter's* equator. The first measures, made when the planet was low and the motion very great, viz. in 1895 October and November, gave a mean distance of 4½″ from the Equator north.

This distance is probably in excess of the true value. The following is a complete list of the results derived from the measures from January 30 to May 10, 1896. Under *a* are given the distance from the Equator; Δ is the distance of the planet from the Earth; B is the B of Mr. Marth's ephemerides; and *b* gives the values under *a* reduced to Δ=5·20.

a (″)	Δ	B (°)	*b* (″)	*a* (″)	Δ	B (°)	*b* (″)
+4·4	4·31	+0·48	+3·6	+4·5	4·79	0·59	4·1
4·4	4·33	·50	3·6	4·6	4·90	·59	4·3
5·6	4·36	·52	4·7	4·2	5·05	·58	4·1
5·5	4·37	·52	4·6	4·2	5·09	·58	4·1
4·4	4·44	·54	3·7	4·3	5·20	·57	4·3
4·6	4·47	·55	3·9	3·8	5·24	·57	3·8
4·5	4·51	·56	3·9	4·4	5·28	·56	4·5
5·2	4·61	·57	4·6	4·3	5·33	·56	4·4
4·8	4·68	·58	4·3	4·5	5·36	·55	4·6
4·4	4·72	·58	4·0	4·4	5·54	·52	4·7

Taken in groups of five the means are $4''\cdot1$, $4''\cdot1$, $4''\cdot2$, $4''\cdot4$; and $4''\cdot2$ the mean of all. With the help of Mr. Marth's values of B and the formula

$$\sin(\beta' - B') = \frac{y}{b},$$

the latitude of the two spots is found to be $+14^\circ\cdot2$.

The measures seem to indicate a slight increase in the latitude in the period embraced by the observations. Dr. Lamp (*Ast. Nach.* vol. 140, p. 170) gives the latitude $+12^\circ\cdot3$, 1896 March 23, from micrometric measures of the distance *d*, from the centre of the planet's disc, "unter Vernachlässigung der Neigung der Bahnebene und der Rotationsaxe des Planeten nach der Formel

$$\tan\phi = \frac{b}{a} \cdot \frac{d}{\sqrt{(b+d)(b-d)}}$$

berechnet."

As it is almost certain that a dark spot seen here in 1894 November is identical with the *Grey Spot*, the following observations will probably have some interest for observers of these phenomena.

1894 November 5.—A dark oblong spot under the north equatorial dark band; central transit about $10^h\ 58^m$.

G.M.T. of Transit.		Before the Zero Merid.	Jovicentric Longitude.	G.M.T. of Transit.		Before the Zero Merid.	Jovicentric Longitude.
1894. d	h m	h m	°	1895. d	h m	h m	°
Nov. 5	10 58	3 19	239·3	Feb. 7	8 9·5	3 31·8	232·3
15	9 10·5	3 21	238·2	9	9 46	3 33·8	231·1
17	10 47·5	3 22	237·6	12	7 15	3 34·8	230·6
1895. Jan. 2	8 31	3 28·7	233·8	Mar. 1	6 15	3 39·9	227·6
21	9 5	3 33·6	231·0	Apr. 15	8 38	3 38·8	228·5
26	8 16·5	3 30	233·3				

Measures of the Position of Jupiter's Satellites and their Shadows when in Transit across the Disc.

In the *Monthly Notices* of the Society, Vol. 55, p. 536, Mr. Marth points out "that the most promising means for determining the longitudes of the nodes of the orbits (of *Jupiter's* satellites) with accuracy would be found in micrometrical measurements of the rectangular coordinates of the shadows of the satellites near their mid-transits, if these measurements are made about the times when the planes of the orbits pass through the Sun. Though the opportunities of 1884, and at the next nodal passages in 1890, pointed out in Vol. 50, p. 347, appear to have been neglected, observers ought to be reminded of their opportunities offered during the present apparition of *Jupiter*." See also Vol. 44, p. 241. It was in response to this appeal that attempts have been made here on suitable occasions to measure the rectangular coordinates of Satellite I. and also of the shadows of I. and III.

It was very soon found that the measurements of the x coordinate could have no value owing to the swaying to and fro of the image of *Jupiter* due mostly no doubt to imperfect driving of the clock.

The measures were made with the Simms Parallel-wire micrometer and the 9⅓-inch Cooke Equatorial Refractor, power 282. The times are in Greenwich Mean Time. 1896 February 23. Clear, calm; fair definition. Ingress of shadow of Satellite III. about $6^h\ 11^m$; central about $7^h\ 57^m$; egress at $9^h\ 44^m$.

The micrometer was carefully adjusted on a bright and then on a faint star, then set to the given position angle and clamped. The measurement went on continuously from $6^h\ 30^m$ till $9^h\ 20^m$. In column *a* is given the distance from the centre of the shadow to the S. pole of the apparent disc, and in *b* the distance to the N. pole; *c* gives the sum of these distances; *d* the number of double measures; *e* the difference from the mean.

a	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
"	"	"			"	"	"		
18·4	24·2	42·6	2	−0·5	18·9	24·9	43·8	2	+0·7
17·7	25·2	42·9	2	−0·2	18·3	25·3	43·6	2	+0·5
18·0	24·5	42·5	2	−0·6	18·3	25·3	43·6	2	+0·5
18·0	24·1	42·1	2	−1·0	18·3	25·2	43·5	2	+0·4
18·3	24·2	42·5	2	−0·6	18·4	24·9	43·3	2	+0·2
18·3	24·9	43·2	2	+0·1	18·0	25·3	43·3	2	+0·2
18·0	25·0	43·0	2	−0·1	17·7	24·6	42·3	4	−0·8
18·4	25·3	43·7	2	+0·6	18·0	24·9	42·9	2	−0·2
17·7	24·6	42·3	2	−0·8	18·0	24·8	42·8	6	−0·3
18·0	25·3	43·3	2	+0·2	18·4	25·0	43·4	2	+0·3
18·3	25·9	44·2	2	+1·1	18·4	25·0	43·4	2	+0·3
18·4	25·6	44·0	2	+0·9	17·8	24·7	42·5	6	−0·6

Mean of numbers in column $c = 43''\cdot 1$.

All measures are given to the nearest tenth of a second.

1896 April 6: shadow of III. in transit; shadow central about $7^h\ 35^m$. Position angle $103^\circ\cdot 8$.

The measures began at $7^h\ 10^m$ and ended at 8^h.

a	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
"	"	"			"	"	"		
15·9	20·9	36·8	2	−0·9	16·5	21·3	37·8	2	+0·1
16·4	20·7	37·1	2	−0·6	16·4	21·0	37·4	2	−0·3
16·3	20·9	37·2	2	−0·5	16·5	21·4	37·9	2	+0·2
16·7	21·0	37·7	2	0·0	16·7	21·1	37·8	2	+0·1
16·9	21·3	38·2	2	+0·5	16·6	21·4	38·0	2	+0·3
16·7	20·7	37·4	2	−0·3	16·5	21·4	37·9	2	+0·2
16·4	20·9	37·3	2	−0·4	16·8	20·8	37·6	2	−0·1
16·8	21·5	38·3	2	+0·6	16·5	21·5	38·0	2	+0·3
16·7	21·0	37·7	2	0·0	16·9	21·0	37·9	2	+0·2
16·6	20·7	37·3	2	−0·4	17·0	21·0	38·0	2	+0·3

Mean $= 37''\cdot 7$.

The webs of the micrometer were brought up to the limbs of the planet and then placed just on them. One revolution of the screw$=13''\cdot837$; one division of the divided head$=0''\cdot138$; thickness of the web about $0''\cdot2$.

1896 March 18: shadow of Satellite I. in transit; ingress $7^h\ 55^m$; egress $10^h\ 9^m\ 30^s$; Position angle $102^\circ\cdot5$.

When near mid-transit six double measures were made from shadow to N. and S. limbs of *Jupiter*:—

Distance from N.	20·6	21·2	21·2	21·0	21·0	21·2
Distance from S.	19·4	19·8	19·1	19·1	18·9	19·2
The sums are	40·0	41·0	40·3	40·1	39·9	40·4

Mean$=40''\cdot3$. Differences $-0''\cdot3$, $+0\cdot7$, $0\cdot0$, $-0\cdot2$ $-0\cdot4$, $+0\cdot1$.

The definition being good and the image fairly steady, the following measures of the x coordinate were made.

a from W. limb; *b* from E. limb; *c* the sum of *a* and *b*; *d* the number of double measures; *e* difference from the mean.

a	b	c	d	e	a	b	c	d	e
″	″	″		″	″	″	″		″
27·5	15·2	42·7	2	−0·2	21·3	22·1	43·4	2	+0·5
27·0	15·5	42·5	2	−0·4	21·7	22·5	44·2	2	+1·3
27·5	15·5	43·0	2	+0·1	20·3	23·8	44·1	2	+1·2
24·9	17·3	42·2	2	−0·7	17·8	25·2	43·0	6	+0·1
24·9	18·1	43·0	2	+0·1	13·4	30·0	43·4	2	+0·5
24·2	19·2	43·4	2	+0·5	15·2	27·7	42·9	2	0·0
22·1	19·5	41·6	2	−1·6	15·2	28·1	43·3	2	+0·4
20·1	21·4	41·5	2	−1·4					

Mean $=42''\cdot9$.

The above measures were made continuously from $8^h\ 25^m$ till $9^h\ 20^m$.

The shadow moved along the bright central zone at a distance of $1''\cdot7$ from the north edge of the ruddy band (double) just south of *Jupiter's* equator.

1896 March 18: Satellite I. in transit; ingress, $6^h\ 52^m\ 25^s$; egress, $9^h\ 8\frac{1}{2}^m$.

This was a dark transit, the satellite appearing as a dusky round spot. When it was central three measures of its distance from the north and three from the south limb were made:—

From north $=21''\cdot4$ From south $=18''\cdot1$ Sum. $=39''\cdot5$.

Three sets of measures from the east and west limbs were made between $7^h\ 47^m$ and $7^h\ 54^m$:—

From East Limb.	From West Limb.	Sum.
18″·7	23″·9	42″·6
18·7	24·5	43·2
17·6	23·5	41·1

Mean $=42''\cdot3$; differences $+0\cdot3$, $+1\cdot1$, $-1\cdot2$.

1896 April 26: Shadow of I. in transit; ingress, $6^h\ 27^m$; egress, $8^h\ 47^m$. Position angle $104^\circ\cdot1$.

When nearly central (but on east side of central meridian) the following measures were made:—

Distance from North Pole.	Distance from South Pole.	Sum.	Differences.
18″·0	16″·9	34″·9	−0″·5
18·0	17·0	35·0	−0·4
18·4	17·0	35·4	0·0
18·2	17·3	35·5	+0·1
18·4	16·9	35·3	−0·1
18·8	16·9	35·7	+0·3
18·8	17·0	35·8	+0·4
18·8	17·1	35·9	+0·5
18·4	16·6	35·0	−0·4
18·9	17·0	35·9	+0·5

Mean $=35''\cdot4$.

The shadow was central about $7\frac{1}{2}^h$. It moved along the bright central zone at a distance of $1''\cdot4$ from the north edge of the ruddy double band just south of *Jupiter's* equator.

Observations of Phenomena of Jupiter's Satellites with the $9\frac{1}{3}$-inch Cooke Equatorial Refractor at Mr. Crossley's Observatory, Bermerside, Halifax, in 1895–6. By Joseph Gledhill.

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	G.M.T. of *N. Almanac.*
1895.				h m s	h m s
Oct. 29	I.	Ec. D.	Fading	15 6	15 7 19
			Bisection?	15 7	
			Just gone	15 7 40	
	II.	Ec. D.	Fading	16 35	16 35 58
			Bisection?	16 36	
			Just gone	16 36 50	
Nov. 30	I.	Ec. D.	Fading	11 34	11 36 16
			Bisection?	11 35	
			Just gone	11 36 41	

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	G.M.T. of *N. Almanac.*
				h m s	h m s
1895. Dec. 1	IV.	Ec. R.	First seen	11 54 3	11 58 34
			Bisection	11 59	
9	I.	Oc. R.	Bisection	11 13	11 15
			Ext. contact	11 15	
1896. Jan. 24	I.	Oc. R.	Ext. contact	10 35	10 34
Feb. 6	II.	Ec. R.	First seen	7 48 16	7 48 3
			Bisection	7 52	
			Full?	7 54	
	IV.	Ec. R.	First seen	12 13 10	12 17 19
			Bisection?	12 18	
			Full?	12 23	
9	I.	Ec. R.	First seen	8 49 39	8 49 59
			Bisection	8 51	
			Full	8 54	
13	II.	Ec. R.	First seen	10 24	10 23 35
			Bisection?	10 25	
23	III.	Sh. I.	Bisection	6 11	
			Int. contact	6 13	6 14
	IV.	Ec. R.	First seen	6 18 52	6 22 27
			Bisection	6 24	
			Full	6 29	
	III.	Tr. E.	Bisection	6 59	7 2
			Ext. contact	7 1	
	I.	Oc. D.	Ext. contact	9 33	9 39
			Bisection	9 34	
			Just gone	9 35 30	
	III.	Sh. E.	Int. contact	9 40 30	9 54
			Bisection	9 44	
			Ext. contact	9 45 30	
24	I.	Tr. I.	Ext. contact	6 59 20	6 58
			Bisection	7 1	
			Int. contact	7 2	
Mar. 1	III.	Tr. I.	Ext. contact	6 49	6 49
			Bisection	6 51	
			Int. contact	6 54	
	III.	Sh. I.	Bisection	10 12 30	10 13
			Int. contact	10 14	
2	I.	Tr. I.	Ext. contact	8 47	8 45

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	G.M.T. of *N. Almanac.*
1896.				h m s	h m s
			Bisection	8 48 30	
			Int. contact	8 50	
	I.	Sh. I.	Int. contact	9 40	9 37
Mar. 8	III.	Tr. I.	Int. contact	10 25	10 19
9	II.	Ec. R.	First seen	7 26 58	7 27 32
			Bisection ?	7 29	
			Full ?	7 30	
	I.	Tr. I.	Ext. contact	10 34 50	10 33
			Bisection	10 36 20	
			Int. contact	10 38	
	I.	Sh. I.	Bisection	11 34	11 31
			Int. contact	11 35 30	
12	III.	Ec. R.	First seen	7 41 31	7 41 57
			Bisection	7 46	
			Full	7 49	
16	II.	Ec. R.	First seen	10 2 20	10 2 46
			Bisection	10 5	
			Full ?	10 8	
17	I.	Oc. D.	Ext. contact	9 29 51	9 31
			Bisection	30 46	
			Just gone	32 1	
18	I.	Tr. I.	Ext. contact	6 50 40	6 49
			Bisection	6 52 25	
			Int. contact	6 54	
	I.	Tr. E.	Int. contact	9 7	9 9
			Bisection	9 8 30	
			Ext. contact	9 11	
	I.	Sh. E.	Int. contact	10 8	10 15
			Bisection	10 9 30	
			Ext. contact	10 12 45	
19	III.	Oc. R.	Bisection	7 12	7 15
	III.	Ec. D.	Fading	8 4 30	8 9 38
			Bisection	8 6 30	
			Just gone	8 11 33	
	IV.	Sh. E.	Int. contact	8 28	8 48
			Bisection	8 30 30	
			Quite off ?	8 35	
23	II.	Oc. D.	Ext. contact	7 28 20	7 28
					O O

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	G.M.T. of *N. Almanac.*
1896.				h m s	h m s
			Bisection	7 30 30	
			Just gone	7 31 50	
Mar. 30	II.	Oc. D.	Ext. contact	9 56 10	9 57
			Bisection	9 58 2	
			Just gone	5 59 10	
Apr. 2	III.	Oc. D.	Ext. contact	11 2 30	11 6
			Bisection	11 6 20	
			Just gone	11 11 20	
	I.	Ec. R.	First seen	11 13 0	11 13 14
			Bisection	11 15 30	
			Full	11 18 30	
3	I.	Tr. E.	Bisection	7 18	7 19
			Ext. contact	7 20	
	I.	Sh. E.	Int. contact	8 28 40	8 34
			Bisection	8 30 20	
8	II.	Tr. E.	Int. contact	9 35	9 43
			Bisection	9 36 30	
			Ext. contact	9 38 30	
	II.	Sh. I.	Int. contact	9 19	9 17
9	I.	Oc. D.	Ext. contact	9 32 50	9 35
			Bisection	9 34 40	
			Last seen	9 35 50	
10	I.	Tr. I.	Ext. contact	6 55 20	6 52
			Bisection	6 57	
			Int. contact	6 58 10	
	II.	Ec. R.	First seen	7 5 50	7 5 35
			Bisection	7 8	
			Full	7 10	
	I.	Sh. I.	Int. contact	8 10	8 8
	I.	Tr. E.	Int. contact	9 8	9 12
			Bisection	9 10	
			Ext. contact	9 11 30	
11	I.	Ec. R.	First seen	7 37 21	7 37 28
			Bisection	7 39	
			Full	7 41	
13	III.	Tr. E.	Bisection	8 35 30	8 39
			Ext. contact	8 39 30	
	IV.	Ec. D.	Fading	7 52	7 56 58
			Bisection	7 55	
			Last seen	7 59 40	

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	G.M.T. of *N. Almanac.*
1895.				h m s	h m s
Apr. 17	II.	Ec. R.	First seen	9 40 25	9 40 31
			Bisection	9 42 30	
			Full	9 45	
18	I.	Ec. R.	First seen	9 32 50	9 32 56
			Bisection	9 34 30	
			Full	9 37	
20	III.	Tr. I.	Ext. contact	9 0 40	8 59
			Bisection	9 3 30	
			Int. contact	9 5 22	
21	IV.	Tr. E.	Int. contact	8 35	8 35
			Bisection	8 37	
			Ext. contact	8 41	
24	III.	Ec. R.	First seen	7 43 34	7 42 48
			Bisection	7 47	
			Full	7 51	
25	I.	Oc. D.	Ext. contact	7 51 30	7 53
			Bisection	7 54	
			Just gone	7 55 5	
26	I.	Tr. E.	Int. contact	7 27	7 30
			Bisection	7 29 37	
			Ext. contact	7 31	
May 3	I.	Sh. I.	Int. contact	8 24	8 21
	II.	Sh. E.	Quite off	9 20	9 26
	I.	Tr. E.	Int. contact	9 24	9 26
			Bisection	9 25	
			Ext. contact	9 26 30	
10	II.	Tr. I.	Ext. contact	6 41	6 43
			Bisection	6 43	
			Int. contact	6 45	
	I.	Tr. I.	Ext. contact	9 6	9 3
			Bisection	9 7 30	
			Int. contact	9 9	
	II.	Tr. E.	Int. contact	9 29	9 38
			Bisection	9 32	
			Ext. contact	9 34	
11	I.	Ec. R.	First seen	9 47 50	9 48 14
			Bisection	9 49 30	
			Full?	9 53	

Notes.

Powers used, 240 and 282.

1895 Oct. 29, planet low; bad definition. Nov. 30, windy; planet low; much motion. Dec. 1, clouds: violent motion. Dec. 9, stormy; no definition. 1896 Jan. 24, windy and wet. Feb. 6, bad definition. Feb. 9, planet low; much boiling. Feb. 13, overcast sky. Feb. 23, much motion. Feb. 24, good definition. Mar. 1, stormy. Mar. 2, very stormy. Mar. 8, stormy. Mar. 9, good definition. Mar. 12, misty. Mar. 16, stormy. Mar. 17, windy; clouds. Mar. 18, good definition. Mar. 19, good. Mar. 23, much cloud. Mar. 30, much cloud. Apr. 2, clouds. Apr. 3, good. Apr. 8, good. Apr. 9, windy; cloud. Apr. 10, windy; cloud; much motion. Apr. 11, windy. Apr. 13, good. Apr. 17, fair; cloud. Apr. 18, fair. Apr. 20, good; mist. Apr. 21, good. Apr. 24, fair; in twilight. Apr. 25, bad. Apr. 26, bad. May 3, good. May 10, fair; first obs. made 1^h before sunset. May 11, fair.

The powers used were 150 when definition was bad, 240 on most occasions, and 330 and 470 when the image was very steady and the sky clear.

On certain Phenomena presented by Jupiter's Satellites and their Shadows during Transit, with a Note on the Red Spot; and on some Methods of observing the Transits of Bright and Dark Spots across the Central Meridian. By J. Gledhill.

Careful observations of the changes which the satellites and their shadows undergo while in transit across the disc of Jupiter are slowly accumulating. Among recent contributors the names of Pritchett, Trouvelot, Tebbutt, Barnard, Denning, Spitta, and Williams may be mentioned. The elaborate researches of Spitta, together with the suggestions and theories of Burton, Proctor, Schaeberle, Holden, Hough, Williams, and others, constitute a real advance in the direction of a scientific explanation of these interesting phenomena. It was with the view of widening the basis for such investigations that the following observations were made. The instrument used was the $9\frac{1}{3}$-in. Cooke equatorial refractor, powers 240 and 270, Huyghenian, and 282 on the Simms' micrometer. The observations were begun in the early morning hours of 1895 October, and concluded in the early evenings of May of the present year.

Satellite I.

Satellite I. in transit 1896 March 2: ingress at $8^h\ 48\frac{1}{2}^m$; invisible about $9^h\ 10^m$. It passed along the bright central zone of *Jupiter*.

Satellite I. in transit, 1896 March 9: ingress at $10^h\ 36^m\ 20^s$. It traversed the bright central zone just below (to north of) the ruddy double belt, and was a bright and conspicuous object when just within the disc. At $10^h\ 42^m$ it was less bright, and gradually grew fainter till $10^h\ 55^m$, when it was just visible; it was invisible at 11^h. At $11^h\ 10^m$ it reappeared as a very faint

dusky round spot, was darker at $11^h\ 15^m$, and easily seen as a dusky spot at $11^h\ 30^m$; central about $11^h\ 38^m$, faint at $11^h\ 50^m$, and seen with difficulty at 12^h.

Satellite I. in transit 1896 March 18: ingress at $6^h\ 52^m\ 25^s$, just visible as a bright disc at $7^h\ 10^m$, invisible at $7^h\ 15^m$, and till $7^h\ 30^m$; at $7^h\ 33^m$ it was seen as a dusky spot; it grew darker, and so continued till $8^h\ 30^m$; at $8^h\ 40^m$ it was less dark; very faint at $8^h\ 50^m$, and invisible at 9^h. It was not so bright when just about to leave the disc as it was at ingress when just within the eastern limb.

Satellite I. in transit, 1896 March 25: ingress about $8^h\ 40^m$; brighter than the limb of *Jupiter* when just within the disc at $8^h\ 50^m$; very faint at 9^h; invisible at $9^h\ 10^m$; a dusky spot at $9^h\ 30^m$ and 10^h; darker at $10^h\ 15^m$ and onwards; clouds prevented further observation. The satellite traversed the bright central zone about $1\frac{1}{2}''$ to the north of the ruddy double band which lies just to the south of *Jupiter's* equator.

Satellite I. in transit 1896 April 10: ingress at $6^h\ 57^m$; it moved along the bright central zone and near the ruddy belt; was much brighter than the adjacent surface of *Jupiter* at ingress; growing faint at $7^h\ 10^m$; very faint at $7^h\ 15^m$; invisible at $7^h\ 30^m$; reappeared as a grey spot at about $7^h\ 40^m$, and so continued till $8^h\ 50^m$; invisible at 9^h; brightening at $9^h\ 5^m$.

Satellite I. in transit 1896 April 17: ingress about $8^h\ 46^m$; brighter than the limb of *Jupiter*; grew gradually fainter, and was invisible at $9^h\ 10^m$; reappeared at $9^h\ 30^m$ as a grey spot.

The Shadow of Satellite I.

On 1896 March 18 the shadow was slightly elongated in a direction parallel to the belts, and seemed smaller at ingress than just before it left the disc.

In transit 1896 April 3: ingress at $8^h\ 30^m\ 20^s$; clouds prevented observation until the shadow had passed the central meridian of *Jupiter's* disc. Between the c. meridian and the western limb the shadow for some time appeared perfectly circular; it then became elongated in a north and south direction, then showed a penumbral fringe on its east and west sides, and then became elongated in a direction not quite parallel to the belts of *Jupiter*.

Satellite II.

In transit April 8: ingress about $6^h\ 48^m$; not seen from 7^h to 9^h; still invisible at $9^h\ 20^m$; quite bright and near the western limb of *Jupiter* at $9^h\ 30^m$.

Satellite III.

In transit 1896 March 1: ingress at $6^h\ 51^m$; at 7^h invisible; seen as a dusky spot at $7^h\ 20^m$; it so remained till $9^h\ 40^m$; at

$9^h\ 55^m$ it was not so dark; at $10^h\ 5^m$ not easily seen; at $10^h\ 10^m$ invisible.

In transit 1896 March 8: brighter than the limb of *Jupiter* at ingress; soon became a dark spot. It was on the ruddy belt just south of the equator. The weather was bad, and further observations impossible.

In transit 1896 April 13: the satellite became quite dark, nearly as black as a shadow, soon after ingress, and continued so all the way across the disc of *Jupiter* till $8^h\ 18^m$, when it became less dark; grew gradually fainter till $8^h\ 25^m$; was invisible at $8^h\ 30^m$ and $8^h\ 34^m$, and quite bright at $8^h\ 35^m$, when near egress.

In transit 1896 April 20: it moved along the ruddy belt just south of *Jupiter's* equator; was brighter than the adjacent surface of the planet at $9^h\ 6^m$; growing fainter at $9^h\ 10^m$; still easily seen at $9^h\ 15^m$; just visible at $9^h\ 23^m$; appeared as a grey spot at $9^h\ 25^m$; darker at $9^h\ 30^m$; at 10^h nearly as dark as a shadow, and so continued till after 12^h.

The Shadow of Satellite III.

In transit 1896 February 23: ingress at $6^h\ 13^m$; very large, black, distinctly elongated in a direction not quite parallel to the belts of *Jupiter*, and so remained for half an hour, then became circular. It was a most striking object for some time, indeed, until it had passed the central meridian. As it passed away from the meridian westward it became altogether a less conspicuous object, and so remained quite up to egress. The definition was so good that all the stages of the egress were easily observed—round when in contact, then imperfect, then half had disappeared, then a black crescent-like form, finally, a thick black curved line, and then total disappearance at $9^h\ 45^m\ 30^s$.

In transit 1896 March 1: ingress at $10^h\ 12^m\ 30^s$, and was black and circular in shape, and of its usual appearance throughout the transit.

An exceptionally fine view of the disappearance of Satellite III. in *Jupiter's* shadow was obtained on 1896 March 19. From 8^h to 9^h the definition was very fine indeed, and the various stages of disappearance were so beautifully seen as to call to mind Professor Pickering's account of these phenomena as seen at Arequipa—"*Phase.* We now come to an observation of which only the most favourably located telescopes are capable, that of watching the change of shape as the satellite enters the shadow of its primary." "The phases of *Jupiter's* satellites are readily observed as they enter into the shadow of the planet, a phenomenon which it is thought but few astronomers have ever seen even with much larger telescopes than the 13-inch" (*Astronomy and Astrophysics*, vol. xi. p. 355). On the present occasion every phase was distinctly and easily seen—full orb just before the satellite touched the shadow, slight deformation, bisection, a

delicate crescent-like form, a fine curved line of light, then a minute speck of light just before complete extinction. It is perhaps needless to add that no trace of the penumbra of *Jupiter's* shadow was seen on the satellite, a very high power and a still finer sky being necessary for such an observation.

Satellite IV.

In transit 1896 April 21: ingress about $3^h\ 56^m$; when first seen, before sunset, it was a fine object well advanced on the disc of *Jupiter*; it was circular and as black as a shadow, and so remained till it approached the western limb, when it became smaller but not less dark. When one half of the satellite still remained on the disc, the other half could not be seen against the dark sky; and even when the whole disc of the satellite was off the planet it was probably no brighter than one of the grey belts. At about 9^h it became brighter. During transit it moved along the south edge of the ruddy belt.

The Shadow of Satellite IV.

In transit 1896 March 19: watched it from 6^h till egress; circular till $7^h\ 15^m$; then distinctly elongated in a direction perpendicular to the belts of *Jupiter*, and thus remained till $7^h\ 45^m$. It moved along the ruddy band.

Note on the Red Spot, &c.

Throughout the whole of the present apparition of *Jupiter* the Red Spot was carefully looked for when in transit, but was never, even on nights of good definition, distinctly and steadily seen. Its outline was occasionally seen for a moment. No colour was ever seen within the outline. Some adjacent features, however, could not be overlooked, viz. the *Preceding Shoulder*, the *Following Shoulder*, and the great trough between them under the Red Spot. A few measures were made of the distance from shoulder to shoulder, but owing to the faintness of the preceding shoulder they were but rough: 1896 February 26, $11''\cdot8$; $11''\cdot1$ on March 12; and $11''\cdot9$ on April 29, all reduced to $\Delta=5\cdot20$. The depth of the trough, from the south edge of the south equatorial belt (here quite narrow) to the north edge of the south temperate band, and through the Red Spot, was $4\frac{1}{2}''$ on 1896 March 12.

Although the preceding and following shoulders and the trough between them do not offer any very definite points for the eye to rest on, attempts were made to obtain the times of their transits across the central meridian with the following results:—

The Preceding Shoulder.

1896.	h m	°		h m	°
Mar. 2	8 44	λ = 354·8	Apr. 2	9 16	λ = 351·0
9	9 30	354·4	9	9 59	349
12	7 0	353·5	24	7 33	351·6
16	10 10½	350	May 6	7 35	353·8
19	7 45	353·3			

The Middle of the Hollow or Trough.

Feb. 26	9 55	λ = 6·2	Apr. 9	10 30	λ = 7·0
Mar. 9	9 53	8·4	12	8 0	6·5
12	7 23	7·4	May 6	7 55	5·9
16	10 37½	6·6	9	5 30	8·7
Apr. 2	9 42	6·7			

The Following Shoulder.

Mar. 2	9 32½	λ = 24·1	Apr. 29	7 38	λ = 25·3
9	10 23	26·4	May 6	8 27	25·3
12	7 52	24·9	9	5 58	25·6
16	11 0	26·6	11	7 38	26·2
Apr. 2	10 12	24·8	13	9 17	26·2
9	11 0	25·0			

Note on some Methods of Observing the Transits of Bright and Dark Spots across the Central Meridian.

It has occurred to me that the following notes might be of some use to Fellows of the Society who live at a distance from London, and to whom many of the Continental and American astronomical publications are not readily accessible.

1. *Simple eye-estimations.*—This is no doubt the method in most general use by amateur astronomers, and it may be encouraging to many to know that it was the method exclusively practised by Mr. Barnard for many years. When skilfully used the results obtained are comparable with ordinary micrometrical measures. "Careful eye-estimates," writes Mr. Barnard, "I think, should have the same value as micrometrical measures for determining the times of transit of the spots on *Jupiter*" (*Monthly Notices*, vol lii., p. 11). And again: "Among the observations of the Red Spot I have forty-four complete and carefully estimated transits—that is, observations of the preceding end, middle, and following end of the spot. Twenty-one of these are from a single but careful estimate of each phase. These give a probable error of a transit of the centre from the mean of the three observations $= \pm 1^{m} \cdot 0$. In twenty-three of these transits three estimations were made of each phase; from these I get for the transit of the middle from the mean of the time observations the error

of the transit $= \pm 0^{m}{\cdot}7$" (*Publications of the Astronomical Society of the Pacific*, vol. i., p. 91). He further found that his observations of the Red Spot "indicate a probable error of $\pm 0^{\circ}{\cdot}44$ or $\pm 0^{m}{\cdot}73$ in the determination of the time of transit by a single estimate."

On the other hand, it is well to remember Mr. Marth's warning after he had reduced a large number of estimated times of transit of the Red Spot by various observers. He writes: "The discrepancies between the observations of different observers and on different days point to the existence of some grave sources of error, and show the necessity for greater care and caution" (*Monthly Notices*, vol. xl., pp. 420–428).

Again: Dr. Schmidt paid considerable attention to this subject, and in his papers in the *Astronomische Nachrichten*, Nos. 2,342 and 2,410, discusses 180 observations of transits of the Red Spot. He finds a mean error of $2^{m}{\cdot}57$ for the time of transit; that personal equation affected the results of different observers to an extent varying between $+3^{m}{\cdot}6$ and $-5^{m}{\cdot}8$; and, lastly, he detected a systematic error in the observations depending on the hour angle, its maximum value being 7^{m}. (See also *Astronomy and Astro Physics*, vol. xi., 1892.) On the whole, it may be said that there is a probable error of $\pm 2\frac{1}{2}^{m}$, and a possible one of 7^{m} or 8^{m}, or even more.

2. Webs or wires are placed so as to cut off similar segments of the disc on each side of the central meridian.

3. Webs or wires are placed as tangents to the ends of a spot and the times noted (*a*) when the first web bisects the disc; (*b*) when the webs cut off equal sections of the disc; (*c*) when the second web bisects the disc. The mean of (*a*) and (*c*) should not differ more than 1^{m} from (*b*). This is Professor Pritchett's method (*Astronomische Nachrichten*, vol. xcvi., p. 223).

4. A thick wire (of known thickness) is placed so as to bisect the disc, while another wire is tangent to one limb of the planet. The times are noted (1) when the preceding end of the spot touches the thick wire; (2) when it reappears at the other edge of the wire. Then the mean of the times is the time of transit of that end of the spot. Similarly for the following end. This is Jedrzejewicz's method. (See *Astronomische Nachrichten*, vol. xcix., p. 211.)

5. When Mr. Barnard used a micrometer he "bisected the equatorial belts by a vertical micrometer wire, and noted the time when the object passed behind the wire" (*Monthly Notices*, vol. lii., p. 7).

6. *Micrometer measures from the two limbs of the planet to the spot.*—This is, of course, the best of all, when the atmospheric conditions and the driving of the clock are good. A considerable saving of time is also effected by this method; one has not to wait until the spot is central; its position may be measured nearly as soon as it is distinctly seen; though, of course, the best results are obtained when the spot is not more than 30^{m} from the central

meridian. Measures may be made on one or both sides of the meridian, and they may be repeated three or more times, so as to reduce the accidental errors. This method has been most extensively used by Professor Hough, of the Dearborn Observatory, Chicago. For his fine series of measures, the formulæ necessary for the reduction of the measures to the central meridian, and his careful discussion of them, see the Annual Reports of the Dearborn Observatory, and especially that for 1882. From measures on thirty-one nights he found the mean error of a single pair of measures $\pm 0^{m}\cdot 9$, and $\pm 0^{m}\cdot 4$ for the average mean probable error for any day.

In conclusion, we may gather from the above notes that careful eye-estimates (the line joining the eyes being placed parallel to the belts), on good nights, and after some practice, will be worthy of confidence, and form useful contributions to the study of the phenomena of the planet.

Mr. E. Crossley's Observatory,
Bermerside, Halifax.

Note on the Period of T Centauri. By Alex. W. Roberts.

The minimum of *T Centauri* which took place in April 1896 happened at the same time as full moon, and so a direct determination of it was impossible.

Observations taken immediately before and after the minimum indicates that the minimum took place 1896 April 26. A minimum (observed both by Lieut.-Col. Markwick and myself) took place on 1895 April 26, and between these two dates there are four light variations, three of which have been observed at Lovedale. We thus obtain for *T Centauri* a period of 91·5 days, a period in satisfactory agreement with that already determined (*Monthly Notices*, March 1896, vol. lvi., p. 349), viz., 91·2 days.

In his *Ephemeriden veränderlicher Sterne für* 1896, page 2, Dr. Hartwig considers that a period of 360 days satisfies the earlier measures. Considering four periods to have taken place in 360 days we obtain a period of 90 days. Still some uncertainty must surround a determination of this kind, inasmuch as it is obtained simply from observations taken at or near maximum, and the maximum of *T Centauri* is not so distinctly marked as the minimum phase.

I hope by the close of the year to deal more fully with this, as well as with other southern long period variables; my present purpose, however, is fulfilled in substantiating the period given in the paper already referred to.

Lovedale:
May 1896.

Observations of Comet b 1896 (Swift) made at the Royal Observatory, Greenwich

(Communicated by the Astronomer Royal.)

The observations were made with the Sheepshanks' Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

1896.	Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log Factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log Factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
	d h m s		m s	s		′ ″	″			h m s	° ′ ″	
May	9 9 46 51	A. C.	+0 24·26	0·00	9·3795	+1 23·2	+0·2	0·8912*n*	3	2 6 19·73	26 9 24·6	*a*
	10 9 45 22	W.	+2 35·33	0·00	9·3230	−6 17·2	−0·8	0·8909*n*	6	1 59 24·59	25 17 25·1	*b*
	12 9 50 47	A. C.	+0 27·47	0·00	9·0713	−1 0·2	−0·2	0·8914*n*	6	1 45 13·44	23 45 39·7	*c*
	14 9 35 3	B.	−3 40·71	0·00	8·9696	+0 4·3	0·0	0·8870*n*	4	1 30 55·58	22 29 2·9	*d*
	20 9 54 18	A. C.	+4 3·49	0·00	9·4701*n*	−2 50·9	−0·4	0·8651*n*	3	0 47 24·48	19 44 46·4	*e*
	30 10 32 12	B.	−1 25·67	−0·02	9·9869*n*	+3 5·2	+0·2	0·7213*n*	5	23 36 53·09	17 34 14·3	*f*
June	1 10 43 2	A. C.	−4 18·24	−0·03	0·0324*n*	+4 22·3	+0·2	0·6644*n*	3	23 23 12·22	17 22 9·4	*g*
	5 10 41 9	,,	−2 44·78	+0·02	0·0719*n*	−2 13·8	−0·1	0·5733*n*	3	22 56 23·38	17 9 54·6	*h*
	6 13 23 25	B.	−0 51·81	+0·02	0·0551*n*	+3 25·1	0·0	9·2022	5	...	...	*k*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

May 20.—Comet very faint and ill-defined, owing to moonlight.
,, 30.—Comet extremely faint, with very slight central condensation.
June 1.—Comet very faint.
,, 5 and 6.—Comet exceedingly faint and ill-defined; barely visible.

The initials A. C., B., W., are those of Mr. Crommelin, Mr. Bryant, and Mr. Witchell respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1896·0.	Assumed N.P.D. 1896·0.	Authority.
		h m s	° ′ ″	
a	BD + 63° No. 305	2 5 56·91	26 8 5·3	Greenwich Observations, 1896.
b	Bradley 270	1 56 50·78	25 23 46·3	Greenwich Ten-Year Catalogue, 1880, and Observations, 1893, 1894, 1895.
c	BD + 66° No. 167	1 44 47·64	23 46 42·0	Pulkova Catalogue (Romberg), 1875.
d	ω Cassiopeiæ	1 34 38·06	22 28 59·5	Greenwich Ten-Year Catalogue, 1880, and Observations, 1888, 1891, 1894.
e	Groombridge 148	0 43 22·79	19 47 33·6	Greenwich Observations, 1894.
f	Oeltz. Arg. (N) 25964	23 38 19·82	17 31 0·0	Oeltzen Argelander (N).
g	BD + 72° No. 1107	23 27 31·29	17 17 37·5	Dorpat Astr. Gesell. Catalogue.
h	Oeltz. Arg. (N) 25078	22 59 8·34	17 11 58·1	" " " "
k	BD + 72° No. 1071	22 49 55	17 5	Bonn Observations, vol. v.

Star *c* is the double star Σ 168. The companion is of the 12th magnitude.

Royal Observatory, Greenwich:
1896 *June* 12.

Meridian Observations of Comet b 1896 (Swift), at Lower Transit at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Mean Time of Observation.	Observer.	Observed R.A. of ☄.	Observed N.P.D. (Corrected for Parallax and Refraction).
1896. d h m s		h m s	° ′ ″
May 1 12 13 52	W. B.	2 55 30·97	36 11 56·92
4 11 45 5	H. F.	2 38 29·07	31 39 23·33
9 10 53 3	A. C.	2 6 1·35	26 6 48·94
11 10 31 20	B.	1 52 8·29	24 27 57·76

The transit on May 4 was observed on four wires only, and these cannot be identified with certainty. It is possible that the R.A. should be diminished by one interval of the wires or $4^s \cdot 7$.

The initials A. C., B., H. F., and W. B. refer to Mr. Crommelin, Mr. Bryant, Mr. Furner, and Mr. Bowyer respectively.

Cometary Observations at Liverpool Observatory, 1895.
By W. E. Plummer, M.A.

The following observations of Comets have been made with the Equatorial of the Liverpool Observatory during the year 1895. When the comet was sufficiently bright to admit of adequate illumination of the wires of a filar micrometer, the measures have been made with that instrument. With the fainter comets, or under unfavourable circumstances, a micrometer of thick wires, crossed at right angles and placed at an angle of 45° with the meridian, has been employed. In a few cases both forms of micrometer have been used, in order to judge of the relative accuracy of the two methods. Similar observations have also been made on nebulæ, and it appears that while the larger number of wires (nine) over which transits can be made with the filar micrometer gives a greater accuracy to the differences of Right Ascension, the declinations are fairly comparable in the two cases. Observations made with the crossed bars are marked "Ret.," and it has been usual to make five transits of the comet and comparison stars. All the observations have been corrected for differences of refraction, but no corrections for parallax have been applied, except in the case of Encke's Comet, mentioned in the Notes. The whole of the observations have been made by Mr. W. Plummer.

Encke's Comet.

Greenwich Mean Time of Observation.		☄−✱ R.A.	No of Comparisons (α)	Apparent R.A. of Comet.	☄−✱ Declination.	No. of Comparisons (δ)	Apparent Declination of Comet.	Log. Factor of Parallax in (α)	Log. Factor of Parallax in (δ)	Letter of Reference.
	h m s	m s		h m s	′ ″		° ′ ″			
1894. Dec. 19	6 8 35·3	+4 46·11	Ret.	22 16 57·74	+ 0 29·9	Ret.	+ 4 37 39·3	0·3168	0·8208	*a*
20	6 3 9·2	−2 20·54	Ret.	22 16 41·87	− 1 6·1	Ret.	+ 4 30 36·7	0·3108	0·8215	*b*
20	6 3 9·2	+ 24·95	Ret.	22 16 42·02	+ 0 17·3	Ret.	+ 4 30 39·2	0·3108	0·8215	*c*
27	6 2 21·0	+1 35·20	25	22 15 7·13	+ 3 20·4	5	+ 3 40 22·8	0·4198	0·8278	*d*
27	6 2 21·0	+ 50·21	25	22 15 6·90	− 3 25·7	5	+ 3 40 21·5	0·4198	0·8278	*e*
30	5 31 47·4	−1 18·46	Ret.	22 14 23·42	+ 8 15·4	Ret.	+ 3 17 32·6	0·3541	0·8292	*f*
31	6 4 20·1	−1 35·04	27	22 14 6·86	+ 0 12·2	6	+ 3 9 29·3	0·4759	0·8314	*f*
1895. Jan. 8	6 4 16·0	−3 2·59	15	22 10 17·74	+ 1 39·7	4	+ 1 47 30·8	0·5584	0·8394	*g*
18	6 10 3·5	− 24·36	20	21 55 55·21	− 2 44·3	5	− 1 40 39·2	0·6511	0·8519	*h*
22	5 39 20·0	−3 25·04	Ret.	21 43 50·67	+13 5·2	Ret.	− 4 16 10·8	0·6489	0·8584	*i*
22	5 39 20·0	+1 11·72	Ret.	21 43 50·31	+11 59·6	Ret.	− 4 15 58·9	0·6489	0·8584	*j*
23	5 36 22·1	+1 4·57	20	21 39 58·16	+ 7 52·9	5	− 5 4 59·1	0·6594	0·8597	*k*
23	5 36 22·1	−1 56·30	20	21 39 58·07	+ 0 49·5	5	− 5 4 57·8	0·6594	0·8597	*l*

Notes.

December 19.—The comet very feeble, without any noticeable condensation.
December 20.—Wind very troublesome: clock seconds frequently inaudible.
December 30.—Comet well seen: condensation marked.
January 8.—Moonlight, but the observation was thought satisfactory.
January 22.—Altitude very small: greater difficulty in seeing the comparison stars than the comet.
January 23.—Observation difficult: comet very low. The comet was seen on January 25, but no suitable star of comparison could be seen.

This series of observations has been compared with the accurate ephemeris prepared by Dr. O. Backlund, and given in *Ast. Nach.*, No. 3263. The distances from the Earth and the times for aberration have been interpolated from that ephemeris, and the resulting comparisons are as follows:—

Date of Observation.	Observed R.A.	Correction for Parallax.	Seconds of Geocentric R.A.	Seconds of Tabular R.A.	Error of Ephemeris. C−O	Observed Declination.	Correction for Parallax.	Seconds of Geoc. Decl.	Seconds of Tabular Decl.	Error of Ephemeris. C−O
1894.	h m s	s	s	s	s	° ′ ″	″	″		
Dec. 19	22 16 57·74	+0·16	57·90	57·89	−0·01	+4 37 39·3	+ 7·5	46·8	59·6	+12·8
20	22 16 41·87	+0·15	42·02	42·56	+0·54	+4 30 36·7	+ 7·5	44·2	47·7	+ 3·5
20	22 16 42·02	+0·15	42·17	42·56	+0·39	+4 30 39·2	+ 7·5	46·7	47·7	+ 1·0
27	22 15 7·13	+0·21	7·34	7·31	−0·03	+3 40 22·8	+ 7·9	30·7	42·7	+12·0
27	22 15 6·90	+0·21	7·11	7·31	+0·20	+3 40 21·5	+ 7·9	29·4	42·7	+13·3
30	22 14 23·42	+0·28	23·70	22·85	−0·85	+3 17 32·6	+ 8·0	40·6	53·4	+12·8
31	22 14 6·86	+0·24	7·10	5·53	−1·57	+3 9 29·3	+ 8·1	37·4	36·7	− 0·7
1895. Jan. 8	22 10 17·74	+0·31	18·05	15·60	−2·45	+1 47 30·8	+ 8·9	39·7	40·3	− 0·6
18	21 55 55·21	+0·44	55·65	51·45	−4·20	−1 40 39·2	+10·4	28·8	68·1	−39·3
22	21 43 50·67	+0·45	51·12	45·55	−5·57	−4 16 10·8	+11·1	59·7	93·6	−33·9
22	21 43 50·31	+0·45	50·76	45·55	−5·21	−4 15 58·9	+11·1	47·8	93·6	−45·8
23	21 39 58·16	+0·47	58·63	52·36	−6·27	−5 4 59·1	+11·3	47·8	84·1	−36·3
23	21 39 58·07	+0·47	58·54	52·36	−6·18	−5 4 57·8	+11·3	46·5	84·1	−37·6

Swift's Comet (*a*) 1895.

Greenwich Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons (α).	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons (δ).	Apparent Declination of ☄.	Log. Factor of Parallax in (α).	Log. Factor of Parallax in (δ).	Letter of Reference.
1895.	h m s	m s		h m s	′ ″		° ′ ″			
Aug. 24	12 19 7·0	−1 24·97	Ret.	0 36 29·22	−8 44·2	Ret.	+ 5 51 20·6	0·4751	0·8165	*a*
27	12 58 30·3	+5 14·81	15	0 43 9·06	+1 21·6	4	+ 6 1 26·7	0·3193	0·8121	*a*
28	12 6 19·1	+3 10·42	15	0 45 11·50	−6 37·2	4	+ 6 3 50·2	0·4909	0·8158	*b*
28	12 6 19·1	−2 6·56	15	0 45 11·03	−2 15·3	4	+ 6 3 51·7	0·4909	0·8158	*c*
Sept. 23	12 2 5·7	−0 55·29	Ret.	1 20 1·21	+8 20·7	Ret.	+ 5 14 42·0	0·2564	0·8163	*d*
23	12 2 5·7	+0 23·92	„	1 20 1·30	+3 40·8	„	+ 5 14 41·3	0·2564	0·8163	*e*
25	11 58 53·0	+0 16·14	„	1 21 12·65	−0 57·4	„	+ 5 5 23·9	0·2377	0·8171	*d*
25	11 58 53·0	+1 35·02	„	1 21 12·42	−5 38·7	„	+ 5 5 22·0	0·2377	0·8171	*e*
26	11 40 13·4	−0 25·11	12	1 21 43·92	+3 2·4	4	+ 5 0 46·7	0·3135	0·8184	*f*
27	11 55 22·0	+0 5·14	Ret.	1 22 14·19	−1 46·2	Ret.	+ 4 55 58·2	0·2190	0·8180	*f*
27	11 55 22·0	−0 2·44	„	1 22 14·11	+6 43·3	„	+ 4 55 52·8	0·2190	0·8180	*g*
28	12 9 32·3	+0 24·65	„	1 22 41·22	+1 57·4	„	+ 4 51 6·9	0·1015	0·8179	*g*
Oct. 13	11 13 22·5	−0 51·81	„	1 26 16·90	+6 3·5	„	+ 3 49 7·2	0·1070	0·8246	*h*
13	11 13 22·5	−4 37·57	„	1 26 16·57	+1 58·5	„	+ 3 49 4·1	0·1070	0·8246	*i*
16	12 0 40·0	−0 33·44	„	1 26 35·29	−2 43·9	„	+ 3 40 19·8	8·7982	0·8249	*j*
17	11 0 22·0	−2 0·87	„	1 26 40·84	+2 9·3	„	+ 3 38 0·5	0·0888	0·8257	*k*
18	9 57 42·6	−0 32·35	„	1 26 46·50	+2 34·5	„	+ 3 35 53·7	0·3964	0·8279	*l*

Notes.

August 24.—Comet faint and ill-defined.

August 27.—Sky hazy, comet very faint.

September 23.—Individual measures discordant.

September 26.—Haze; the observation very unsatisfactory. The reticule micrometer was tried on this night but the results were very discordant.

September 28.—Transits very irregular and uncertain.

In October the comet was very faint, but the observations fairly accordant.

Perrine's Comet (*c* 1895).

Greenwich Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons (α).	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons (δ).	Apparent Declination of ☄.	Log. Factor of Parallax in (α).	Log. Factor of Parallax in (δ).	Letter of Reference.
1895.	h m s	m s		h m s	′ ″		° ′ ″			
Nov. 18	17 14 21·1	+7 21·26	25	13 48 8·80	−2 15·2	5	+ 0 49 55·7	0·6951	0·8555	*a*
23	17 11 4·0	+0 34·90	20	14 0 36·94	−0 51·2	4	− 2 4 47·0	0·6926	0·8509	*b*
Dec. 1	17 34 16·3	+2 36·71	20	14 30 58·12	+7 17·8	4	− 8 54 58·1	0·6774	0·8641	*c*
2	17 59 6·4	+3 1·12	15	14 36 24·92	+1 46·1	4	−10 4 33·6	0·6537	0·8703	*d*
2	17 59 6·4	−1 17·33	15	14 36 25·18	+4 5·9	4	−10 4 37·0	0·6537	0·8703	*e*

Notes.

November 18.—Comet bright, with some indications of a tail.
November 23.—Comet well seen notwithstanding comparatively low altitude.
December 1 and 2.—Comet bright and easily seen; the comparison stars very faint on account of low altitude; sky transparent.

Brooks' Comet (*d* 1895).

Greenwich Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons (α).	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons (δ).	Apparent Declination of ☄.	Log. Factor of Parallax in (α).	Log. Factor of Parallax in (δ).	Letter of Reference.
	h m s	m s		h m s	′ ″		° ′ ″			
Nov. 28	16 40 30·0	−1 23·22	Ret.	9 25 56·43	−0 17·7	Ret.	+ 2 19 19·0	9·7988	0·8335	*a*
29	16 44 27·2	−1 55·23	,,	9 20 51·02	−7 1·9	,,	+ 6 14 32·6	9·4922	0·8075	*b*
Dec. 9	10 0 5·5	+1 46·10	,,	7 57 33·90	−2 50·3	,,	+48 35 40·6	0·8834	0·5522	*c*
9	10 0 5·5	+0 2·60	,,	7 57 33·57	+2 57·2	,,	+48 35 36·1	0·8834	0·5522	*d*
11	9 23 30·0	−5 23·41	,,	7 29 48·72	+7 46·3	,,	+55 9 15·5	0·9474	0·4550	*e*

Notes.

November 28.—Comet faint and without condensation. The centre of the nebulosity was estimated for the point of observation.
November 29.—The observations very discordant.
December 11.—Sky somewhat overcast. The differences of declination differ in the several transits.

Liverpool Observatory:
1896 *June* 10.

Mean Places of Stars of Comparison.

Encke's Comet.

Date.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	Letter of Reference.
		h m s	s	° ′ ″	″	
1894. Dec. 19	Albany, A.G.Z., No. 7744	22 12 9·27	+2·36	+ 4 36 53·9	+15·5	*a*
20	,, ,, No. 7761	22 19 0·03	+2·38	+ 4 31 27·1	+15·7	*b*
20	,, ,, No. 7754	22 16 4·71	+2·36	+ 4 30 6·3	+15·6	*c*
27	,, ,, No. 7746	22 13 29·60	+2·33	+ 3 36 47·7	+14·7	*d*
27	,, ,, No. 7747	22 14 14·36	+2·33	+ 3 43 32·4	+14·8	*e*
30	,, ,, No. 7752	22 15 39·58	+2·30	+ 3 9 2·8	+14·4	*f*
31	,, ,, No. 7752	...	+2·32	...	+14·3	*f*
1895. Jan. 8	Munich Cat., No. 30666	22 13 21·08	−0·75	+ 1 45 55·9	− 4·8	*g*
18	,, ,, No. 30061	21 56 20·37	−0·80	− 1 37 57·9	− 7·0	*h*
22	Yarnall (1860) No. 9839	21 47 16·50	−0·79	− 4 29 8·0	− 8·0	*i*
22	Schjellerup, No. 8850	21 42 39·39	−0·80	− 4 27 50·5	− 8·0	*j*
23	Stone (Rad.), No. 5858	21 38 54·39	−0·80	− 5 12 43·7	− 8·3	*k*
23	Glasgow (1870), No. 5580	21 41 55·17	−0·80	− 5 5 39·1	− 8·2	*l*

Swift's Comet (*a* 1895).

Date.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	Letter of Reference.
1895.		h m s	s	° ′ ″	″	
Aug. 24	Yarnall (1860), No. 359	0 37 50·93	+3·26	+5 59 42·3	+22·5	*a*
27	" " No. 359	...	+3·32	...	+22·8	*a*
28	60 Piscium	0 41 57·74	+3·34	+6 10 4·3	+23·1	*b*
28	Schjellerup, No. 303	0 47 14·26	+3·33	+6 5 43·9	+23·1	*c*
Sept. 23	Albany, A.G.Z., No. 396	1 20 52·78	+3·72	+5 5 54·9	+26·4	*d*
23	Bonn, D.M., 4°, No. 247	1 19 33·66	+3·72	+5 10 34·2	+26·3	*e**
25	Albany, A.G.Z., No. 396	1 20 52·78	+3·73	+5 5 54·9	+26·4	*d*
25	Bonn, D.M., 4°, No. 247	1 19 33·66	+3·74	+5 10 34·2	+26·5	*e**
26	Albany, A.G.Z., No. 402	1 22 5·28	+3·75	+4 57 17·8	+26·5	*f*
27	" " No. 402	...	+3·77	...	+26·6	*f*
27	" " No. 404	1 22 12·78	+3·77	+4 48 42·8	+26·7	*g*
28	" " No. 404	...	+3·79	...	+26·7	*g*
Oct. 13	" " No. 423	1 27 4·75	+3·96	+3 42 36·4	+27·3	*h*
13	" " No. 450	1 30 50·17	+3·97	+3 46 38·2	+27·4	*i*
16	" " No. 423	1 27 4·75	+3·98	+3 42 36·4	+27·3	*j*
17	" " No. 457	1 28 37·73	+3·98	+3 35 23·9	+27·3	*k*
18	" " No. 424	1 27 14·87	+3·98	+3 32 51·9	+27·3	*l*

* This star's place has been taken from the *Astronomical Journal*, No. 357.

Perrine's Comet (*c* 1895).

Date.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	Letter of Reference
1895.		h m s	s	° ′ ″	″	
Nov. 18	Albany, A.G.Z., No. 4789	13 40 45·64	+1·90	+ 0 52 27·9	−17·0	*a*
23	Munich Cat., No. 9819	14 0 0·08	+1·96	− 2 5 21·1	−17·1	*b*
Dec. 1	,, ,, No. 10285	14 28 19·33	+2·08	− 9 1 59·2	−16·7	*c*
2	Stone (Rad.), No. 3788	14 33 21·70	+2·10	−10 6 3·1	−16·6	*d*
2	Munich Cat., No. 10464	14 37 40·41	+2·10	−10 8 26·3	−16·6	*e*

Brooks' Comet (*d* 1895).

Date.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	Letter of Reference
Nov. 28	Munich Cat., No. 4254	9 27 16·10	+3·55	+ 2 19 45·2	− 8·5	*a*
29	Paris Cat., No. 11654	9 22 42·54	+3·71	+ 6 21 44·2	− 9·7	*b*
Dec. 9	Bonn, A.G.Z., No. 6354	7 55 41·29	+6·51	+48 38 18·9	−12·0	*c*
9	,, ,, No. 6375	7 57 24·48	+6·49	+48 32 26·7	−12·2	*d*
11	Helsingfors, A.G.Z., No. 5193	7 35 4·71	+7·42	+55 1 38·6	− 9·4	*e*

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On the Orbit of 42 Comæ Berenicis $=\Sigma 1728$.

By T. J. J. See, A.M., Ph.D. (Berlin.)

In the course of a general revision of the orbits of double stars I had occasion some three years ago to examine the theory of 42 *Comæ Berenicis*. Professor Burnham generously placed at my disposal a list of measures which was nearly complete, and I have since added to it such as were omitted, and made also new observations during 1895. When scrutinised under the fine definition of the 26-inch Clark refractor of the Leander McCormick Observatory of the University of Virginia, the pair proved to be excessively close, and with a power of 1,300 could only be elongated. As the object has now become single in all existing telescopes, and cannot again be separated until about 1899, I take this opportunity to present to the Society an investigation of the orbit of this peculiarly interesting star. The only previous investigation of the orbit is that made by Otto Struve and Dubiago in 1874 (*Monthly Notices*, 1874–75, p. 367). Struve's elements are as follows :—

$P = 25{\cdot}71$ years.	$\Omega = 11{\cdot}^\circ 0$
$T = 1869{\cdot}92$	$i = 90^\circ$
$e = 0{\cdot}480$	$\lambda = 99^\circ{\cdot}18$
$a = 0''{\cdot}657$	

The method followed here is not very different from that employed by Struve, except that the results are based on the measures of all reliable observers and are rendered more complete by observations made since 1874—indeed, up to the occultation of 1896.

It will be seen from an examination of the table at the end of the paper that the motion is to all appearances exactly in the line of vision, and hence, with the exception of the node and inclination, the elements are based wholly on the measures of distance. Struve's elements are fairly good, and it would, therefore, be sufficient to apply differential corrections to his values; but as I had independently adopted a graphical method similar to that employed by him, it seemed of interest to make use of it in deriving approximate values directly from the phenomena.

When the elements had been approximately determined the observations furnished 52 equations of condition for determining five unknowns; weights were assigned in proportion to the number of nights, and when the least square solutions had been effected the corrected elements came out as follows:—

$P = 25{\cdot}556$ years.	$\Omega = 11^\circ{\cdot}9$
$T = 1885{\cdot}69$	$i = 90^\circ$
$e = 0{\cdot}461$	$\lambda = 280^\circ{\cdot}5$
$a = 0''{\cdot}6416$	$n = \pm 14^\circ{\cdot}09$

Apparent orbit:

Distance of star from centre	$= 0''{\cdot}054$
Length of major axis	$= 1''{\cdot}147$
Length of minor axis	$= 0{\cdot}00$
Angle of major axis	$= 11^\circ{\cdot}9$
Angle of *Periastron*	$= 11^\circ{\cdot}9$

The apparent phenomena are shown in the accompanying diagram, to which is added a figure of the real orbit. A

graphical illustration of the motion, obtained by taking the x axis to represent the time, while the ordinates represent the distances, was employed in finding the approximate values of the elements; the curve here given represents the motion according to the elements as corrected.

This orbit of 42 *Comæ Berenicis* is one of the most exact of double-star orbits, and will finally require but very slight improvement. The period can hardly be in error by more than 0·1 year, while a variation of $\pm$0·01 in the eccentricity is not to be anticipated.

Comparison of Computed with Observed Places.

	θ_0	ρ_0	$\theta_0 - \theta_c$	$\rho_0 - \rho_c$	n
	°		°		
1827·83	189·5	obl.	− 2·4	+0·01	2–1
1829·40	191·6	0·64	− 0·3	...	3
1833·37	70·7?	obl.	−21·2	...	1
1834·43	228·3	obl.	+36·4	...	1
1835·39	11·2	...	− 0·7	...	4
1836·41	10·2	0·30	− 1·7	−0·12	3
1837·40	11·0	0·39	− 0·9	−0·11	6
1838·41	11·5	0·36	− 0·4	−0·15	3
1839·42	12·2	0·59	+ 0·3	+0·09	...
1840·60	17·1	0·48	+ 5·2	+0·04	6
1841·40	14·6	0·40	+ 2·7	+0·02	14–7
1842·43	14·7	0·32	+ 2·8	+0·02	7–3
1843·36	single	...	...	...	2
1844·32	189·5	...	− 2·4	...	2
1845·47	single	...	...	...	...
1846·40	66·8?	obl.?	+54·9	...	3
1847·42	195·5	0·20	+ 3·6	+0·02	1
1848·42	192·7	0·27	+ 0·8	0·00	3
1849·42	188·6	0·42	− 3·3	+0·06	3
1850·69	192·3	0·44	+ 0·4	−0·01	4
1851·55	190·9	0·47	− 1·0	−0·04	8–6

	θ_o	ρ_o	$\theta_o - \theta_c$	$\rho_o - \rho_c$	n
	°		°	"	
1852·42	191·0	0·55	− 0·9	−0·01	9–8
1853·28	193·0	0·60	+ 1·1	±0·00	21–16
1854·39	193·5	0·60	+ 1·6	−0·02	14–13
1855·41	193·9	0·59	+ 2·0	−0·02	4–3
1856·59	192·4	0·57	+ 0·5	0·00	14–13
1857·44	193·0	0·47	+ 1·1	−0·04	5–3
1858·42	192·4	0·39	+ 0·5	+0·04	8
1859·36	215·8	0·2 ±	+23·9	+0·06	3
1860·34	3·5 ?	0·2 ±	− 8·4	+0·08	1
1861·40	13·1	0·43	+ 1·2	+0·09	4–2
1862·34	12·4	0·54	+ 0·5	+0·08	11–2
1863·35	10·2	0·53	− 1·7	+0·01	2
1864·42	12·3	0·48	+ 0·4	−0·03	6–4
1865·56	12·4	0·44	+ 0·5	−0·03	13–8
1866·64	8·5	0·40	− 3·4	−0·01	3
1867·62	13·9	0·36	+ 2·0	+0·03	4–2
1868·44	15·8	0·21	+ 3·9	−0·04	2
1869·37	15·2	0·61 ?	...	...	5
1870·45	16·0	0·61	...	...	4
1871·41	194·6	0·61	...	...	3–0
1872·47	200·0	0·61	...	...	3
1873·60	194·7	0·20	+ 2·8	−0·03	5–2
1874·41	189·2	0·30	− 2·7	0·00	2
1875·42	191·3	0·43	− 0·6	+0·03	26–25
1876·40	190·4	0·50	− 1·5	+0·03	16
1877·43	190·9	0·52	− 1·0	−0·01	17–13
1878·40	191·4	0·58	− 0·5	0·00	11–8
1879·40	191·9	0·61	0·0	0·00	12
1880·38	193·0	0·52	+ 1·1	−0·10	8
1881·34	192·3	0·59	− 0·4	−0·02	26–18
1882·52	190·9	0·56	− 1·0	+0·02	22–18

t	θ_0	ρ_0	$\theta_0-\theta_c$	$\rho_0-\rho_c$	n
	°		°	"	
1883·46	192·3	0·52	+ 0·4	+0·09	19–18
1884·40	192·7	0·33	+ 0·8	+0·07	7
1886·46	12·9	0·27	+ 1·0	+0·02	9
1887·43	13·3	0·40	+ 1·4	−0·01	13
1888·33	11·5	0·47	− 0·4	−0·02	7–6
1889·25	11·1	0·55	− 0·8	+0·03	7
1890·38	9·9	0·60	− 2·0	+0·09	16
1891·44	11·0	0·50	− 0·9	+0·05	12
1892·40	11·4	0·43	− 0·5	+0·04	16–13
1893·45	10·2	0·32	− 1·7	+0·01	5
1894·41	9·0	0·23	− 2·9	+0·01	8
1895·29	13·9	0·14	+ 2·0	0·00	3

The University of Chicago :
1896 *March* 30.

Ephemeris for Physical Observations

Greenwich Noon.		P.	L−O.	B.	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b	d.	w.	B′.
1896.		°	°	°	″	″	″	°	°	°
Oct.	7	23·121	16·323	−0·650	33·09	0·13	31·02	7·29	268·66	−0·69
	9	23·187	16·691	0·669	33·21	·14	31·13	7·50	268·61	0·71
	11	23·252	17·054	0·688	33·34	·15	31·25	7·71	268·56	0·73
	13	23·315	17·412	0·707	33·47	·16	31·37	7·41	268·52	0·75
	15	23·376	17·765	0·726	33·60	·17	31·49	8·11	268·48	0.77
	17	23·435	18·112	−0·745	33·74	0·18	31·62	8·30	268·44	−0·79
	19	23·493	18·452	0·764	33·88	·19	31·75	8·48	268·40	0·81
	21	23·548	18·786	0·783	34·03	·19	31·89	8·66	268·36	0·83
	23	23·602	19·114	0·801	34·18	·20	32·03	8·83	268·33	0·85
	25	23·654	19·435	0·820	34·33	·21	32·18	9·00	268·29	0·87
	27	23·704	19·749	−0·838	34·49	0·22	32·33	9·16	268·26	−0.89
	29	23·753	20·056	0·856	34·65	·23	32·48	9·31	268·23	0·91
	31	23·799	20·356	0·874	34·82	·24	32·64	9·45	268·20	0·93
Nov.	2	23·843	20·648	0·892	34·99	·24	32·80	9·59	268·16	0·95
	4	23·886	20·932	0·909	35·17	·25	32·97	9·72	268·13	0·97
	6	23·927	21·208	−0·926	35·35	0·26	33·14	9·84	268·10	−0·99
	8	23·967	21·475	0·943	35·54	·27	33·31	9·95	268·07	1·01
	10	24·005	21·733	0·960	35·73	·27	33·49	10·05	268·04	1·02
	12	24·041	21·983	0·977	35·92	·28	33·67	10·15	268·01	1·04
	14	24·075	22·224	0·994	36·12	·29	33·85	10·24	267·98	1·06
	16	24·107	22·455	−1·010	36·32	0·29	34·04	10·31	267·94	−1·08
	18	24·138	22·676	1·026	36·52	·30	34·23	10·38	267·91	1·10
	20	24·167	22·887	1·042	36·73	·30	34·43	10·43	267·88	1·11
	22	24·195	23·089	1·058	36·94	·31	34·63	10·48	267·85	1·13
	24	24·221	23·281	1·073	37·16	·31	34·83	10·52	267·82	1·14
	26	24·245	23·461	−1·088	37·38	0·32	35·04	10·54	267·79	−1·16
	28	24·268	23·631	1·103	37·60	·32	35·25	10·56	267·76	1·18
	30	24·289	23·790	1·117	37·83	·32	35·46	10·56	267·72	1·19
Dec.	2	24·308	23·937	1·131	38·06	·32	35·67	10·55	267·68	1·21
	4	24·326	24·073	1·145	38·29	·32	35·88	10·53	267·64	1·22
	6	24·342	24·198	−1·158	38·52	0·32	36·10	10·50	267·61	−1·24
	8	24·356	24·310	1·171	38·75	·32	36·32	10·46	267·57	1·25
	10	24·369	24·410	1·184	38·99	·32	36·55	10·41	267·54	1·26

of Jupiter, 1896–97. By A. Marth.

Greenwich Noon.		Brightness in Star Magn.	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A–O.	B.
1896.		m	°	°	°	m	°	°
Oct.	7	−1·37	121·99	147·66	+0·23	50·331	9·0402	−0·4855
	9	−1·38	77·54	87·94	·24	50·149	9·1961	·4938
	11	−1·38	33·09	28·23	·26	49·962	9·3520	·5021
	13	−1·39	348·65	328·53	·27	49·770	9·5078	·5103
	15	−1·40	304·21	268·84	·29	49·573	9·6636	·5185
	17	−1·41	259·79	209·15	+0·30	49·371	9·8193	−0·5267
	19	−1·42	215·38	149·48	·31	49·164	9·9750	·5349
	21	−1·43	170·97	89·81	·33	48·953	10·1307	·5431
	23	−1·44	126·57	30·15	·34	48·737	10·2863	·5513
	25	−1·45	82·19	330·50	·35	48·517	10·4419	·5595
	27	−1·45	37·81	270·86	+0·36	48·293	10·5975	−0·5677
	29	−1·46	353·44	211·24	·38	48·064	10·7530	·5759
	31	−1·47	309·08	151·62	·39	47·832	10·9085	·5841
Nov.	2	−1·49	264·73	92·01	·40	47·596	11·0640	·5923
	4	−1·50	220·40	32·41	·41	47·357	11·2195	·6005
	6	−1·51	176·07	332·82	+0·42	47·114	11·3749	−0·6086
	8	−1·52	131·75	273·24	·43	46·869	11·5303	·6168
	10	−1·53	87·44	213·67	·44	46·620	11·6857	·6250
	12	−1·54	43·15	154·11	·45	46·369	11·8410	·6331
	14	−1·55	358·86	94·57	·46	46·116	11·9963	·6412
	16	−1·56	314·59	35·03	+0·46	45·860	12·1515	−0·6493
	18	−1·57	270·33	335·50	·47	45·603	12·3067	·6575
	20	−1·59	226·07	275·99	·47	45·344	12·4619	·6656
	22	−1·60	181·83	216·49	·48	45·084	12·6171	·6737
	24	−1·61	137·59	156·99	·48	44·822	12·7723	·6818
	26	−1·62	93·37	97·51	+0·48	44·559	12·9274	0·6899
	28	−1·64	49·16	38·04	·48	44·296	13·0825	·6980
	30	−1·65	4·96	338·58	·48	44·032	13·2375	·7061
Dec.	2	−1·66	320·78	279·13	·48	43·768	13·3925	·7142
	4	−1·68	276·61	219·69	·48	43·505	13·5475	·7223
	6	−1·69	232·44	160·27	+0·48	43·242	13·7025	−0·7303
	8	−1·70	188·29	100·85	·48	42·979	13·8574	·7384
	10	−1·71	144·15	41·45	·47	42·718	14·0123	·7465

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b	d.	w.	B'.
1896.	°	°	°	"	"	"	°	°	°
Dec. 12	24·381	24·498	1·196	39·23	·32	36·77	10·35	267·50	1·28
14	24·391	24·574	1·208	39·47	·32	36·99	10·27	267·45	1·29
16	24·399	24·637	−1·219	39·71	0·31	37·22	10·17	267·40	−1·30
18	24·406	24·688	1·230	39·95	·31	37·45	10·07	267·36	1·31
20	24·411	24·726	1·241	40·20	·30	37·67	9·95	267·31	1·32
22	24·415	24·751	1·251	40·44	·30	37·90	9·82	267·26	1·33
24	24·417	24·763	1·261	40·68	·29	38·13	9·68	267·21	1·34
26	24·418	24·763	−1·270	40·92	0·28	38·35	9·53	267·15	−1·35
28	24·417	24·750	1·279	41·16	·27	38·58	9·36	267·09	1·36
30	24·414	24·723	1·287	41·40	·26	38·80	9·18	267·03	1·37
1897.									
Jan. 1	24·410	24·683	1·294	41·64	·25	39·02	8·98	266·97	1·38
3	24·404	24·631	1·301	41·87	·24	39·24	8·78	266·90	1·39
5	24·396	24·565	−1·308	42·10	0·23	39·46	8·56	266·82	−1·40
7	24·387	24·487	1·314	42·33	·22	39·67	8·32	266·74	1·40
9	24·377	24·396	1·319	42·35	·21	39·88	8·08	266·66	1·41
11	24·365	24·293	1·324	42·77	·20	40·08	7·82	266·57	1·41
13	24·351	24·178	1·328	42·98	·19	40·28	7·55	266·47	1·42
15	24·335	24·051	−1·332	43·19	0·17	40·48	7·27	266·36	−1·42
17	24·318	23·913	1·335	43·39	·16	40·67	6·98	266·25	1·42
19	24·300	23·763	1·337	43·58	·15	40·85	6·67	266·12	1·43
21	24·280	23·602	1·339	43·77	·13	41·03	6·36	265·98	1·43
23	24·258	23·430	1·341	43·95	·12	41·20	6·03	265·82	1·43
25	24·235	23·248	−1·341	44·12	0·11	41·36	5·70	265·64	−1·43
27	24·210	23·057	1·341	44·29	·10	41·51	5·35	265·44	1·43
29	24·184	22·856	1·341	44·44	·08	41·65	4·99	265·21	1·43
31	24·156	22·646	1·340	44·59	·07	41·79	4·63	264·95	1·43
Feb. 2	24·127	22·429	1·338	44·72	·06	41·92	4·26	264·64	1·43
4	24·097	22·204	−1·336	44·84	0·05	42·03	3·88	264·27	−1·43
6	24·065	21·972	1·333	44·95	·04	42·14	3·50	263·82	1·42
8	24·032	21·733	1·329	45·06	·03	42·23	3·11	263·25	1·42
10	23·998	21·489	1·325	45·15	·03	42·31	2·71	262·54	1·41
12	23·962	21·240	1·321	45·22	·02	42·39	2·31	261·52	1·41
14	23·925	20·987	−1·316	45·29	0·01	42·45	1·91	260·1	−1·40
16	23·887	20·731	1·310	45·34	·01	42·50	1·50	258·0	1·40
18	23·849	20·472	1·304	45·38	·00	42·53	1·10	254·2	1·39
20	23·810	20·211	1·298	45·41	...	42·56	0·70	246·1	1·39
22	23·770	19·949	1·291	45·42	...	42·57	0·35	220·1	1·38

Greenwich Noon.	Brightness in Star Magn.	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O	*B.*
1896.	m	°	°	°	m	°	°
Dec. 12	−1·73	100·02	242·06	·47	42·458	14·1672	·7545
14	−1·74	55·90	282·68	·46	42·200	14·3221	·7626
16	−1·75	11·79	223·31	+0·45	41·944	14·4769	−0·7706
18	−1·77	327·70	163·96	·44	41·691	14·6317	·7787
20	−1·78	283·62	104·61	·43	41·440	14·7865	·7867
22	−1·79	239·54	45·27	·42	41·192	14·9413	·7947
24	−1·81	195·47	345·95	·41	40·947	15·0960	·8027
26	−1·82	151·42	286 64	+0·39	40·706	15·2507	−0·8107
28	−1·83	107·38	227·34	·38	40·469	15·4054	·8187
30	−1·84	63·35	168·04	·37	40·236	15·5600	·8267
1897.							
Jan. 1	−1·86	19·33	108·76	·35	40·007	15·7146	·8347
3	−1·87	335·31	49·49	·33	39·784	15·8692	·8427
5	−1·88	291·31	350·22	+0·32	39·566	16·0238	−0·8506
7	−1·89	247·32	290·97	·30	39·354	16·1783	·8586
9	−1·90	203·34	231·73	·28	39·148	16·3328	·8665
11	−1·92	159·36	172·49	·27	38·948	16·4873	·8745
13	−1·93	115·40	113·26	·25	38·754	16·6418	·8824
15	−1·94	71·44	54·04	+0·23	38·568	16·7962	−0 8903
17	−1·95	27·49	354·83	·21	38·389	16·9506	·8982
19	−1·96	343·54	295·62	·19	38·217	17·1050	·9061
21	−1·97	299·60	236·42	·18	38·053	17·2594	·9140
23	−1·98	255·67	177·23	·16	37·897	17·4137	·9219
25	−1·98	211·74	118·04	+0·14	37·749	17·5680	−0·9298
27	−1·99	167·81	58·85	·12	37·610	17·7223	·9377
29	−2·00	123·89	359·67	·11	37·480	17·8765	·9456
31	−2·01	79·98	300·49	·09	37·358	18·0307	·9535
Feb. 2	−2·01	36·06	241·32	·08	37·246	18·1849	·9613
4	−2·02	352·15	182·15	+0·07	37·144	18·3391	−0·9691
6	−2·03	308·24	122·98	·05	37·051	18·4932	0·9770
8	−2·03	264·33	63·81	·04	36·968	18·6473	0·9848
10	−2·04	220·42	4·63	·03	36·895	18·8014	0·9926
12	−2·04	176·51	305·46	·02	36·833	18·9555	1·0004
14	−2·04	132·59	246·28	·02	36·780	19·1096	−1·0082
16	−2·04	88·67	187·10	+0·01	36·738	19·2636	1·0160
18	−2·05	44·75	127·92	·00	36·706	19·4176	1 0238
20	−2 05	0·82	68·74	. .	36·684	19·5716	1·0316
22	−2·05	316·89	9·55	...	36 673	19·7255	1·0393

Greenwich Noon.	P.	L – O.	B.	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b	d.	ω.	B′.
1897.	°	°	°	″	″	″	°	°	°
Feb. 24	23·729	19·686	–1·284	45·42	...	42·57	0·32	142·8	–1·37
26	23·688	19·423	1·276	45·41	...	42·56	0·65	111·2	1·36
28	23·646	19·161	1·268	45·38	·00	42·54	1·04	102·2	1·35
Mar. 2	23·605	18·902	1·260	45·34	·01	42·50	1·45	97·0	1·34
4	23·563	18·646	1·251	45·29	·01	42·45	1·86	95·7	1·33
6	23·522	18·393	–1·242	45·23	0·02	42·39	2·26	94·1	–1·32
8	23·480	18·143	1·233	45·16	·02	42·32	2·66	93·17	1·31
10	23·439	17·898	1·224	45·07	·03	42·24	3·06	92·39	1·30
12	23·398	17·659	1·214	44·97	·04	42·15	3·45	91·83	1·29
14	23·358	17·426	1·204	44·86	·05	42·05	3·84	91·36	1·28
16	23·319	17·200	–1·195	44·74	0·06	41·93	4·22	90·98	–1·27
18	23·281	16·981	1·185	44·61	·07	41·81	4·59	90·67	1·26
20	23·244	16·771	1·175	44·47	·08	41·68	4·95	90·40	1·25
22	23·208	16·568	1·165	44·32	·09	41·54	5·31	90·16	1·24
24	23·173	16·374	1·156	44·16	·11	41·39	5·66	89·95	1·23
26	23·139	16·190	–1·147	43·99	0·12	41·23	5·99	89·77	–1·22
28	23·107	16·015	1·137	43·81	·13	41·06	6·32	89·61	1·21
30	23·077	15·851	1·127	43·62	·15	40·89	6·64	89·46	1·20
Apr. 1	23·049	15·697	1·118	43·43	·16	40·71	6·95	89·33	1·19
3	23·022	15·554	1·109	43·23	·17	40·52	7·24	89·21	1·18
5	22·997	15·422	–1·100	43·03	0·19	40·33	7·53	89·10	–1·17
7	22·974	15·302	1·091	42·82	·20	40·13	7·80	89·00	1·16
9	22·954	15·193	1·083	42·60	·21	39·93	8·06	88·91	1·15
11	22·936	15·097	1·075	42·38	·22	39·73	8·31	88·82	1·15
13	22·919	15·013	1·067	42·16	·23	39·52	8·55	88·74	1·14
15	22·905	14·941	–1·059	41·93	0·24	39·30	8·78	88·66	–1·13
17	22·893	14·881	1·052	41·70	·26	39·09	8·99	88·59	1·12
19	22·883	14·832	1·045	41·47	·27	38·87	9·19	88·52	1·12
21	22·876	14·796	1·038	41·24	·28	38·65	9·38	88·46	1·11
23	22·871	14·773	1·032	41·00	·28	38·43	9·56	88·39	1·10
25	22·868	14·761	–1·026	40·76	0·29	38·20	9·72	88·33	–1·10
27	22·868	14·762	1·021	40·52	·30	37·98	9·88	88·27	1·09
29	22·870	14·776	1·016	40·28	·31	37·76	10·02	88·22	1·08
May 1	22·875	14·802	1·012	40·04	·31	37·53	10·15	88·17	1·08
3	22·882	14·840	1·008	39·80	·32	37·31	10·26	88·12	1·07
5	22·891	14·890	–1·004	39·56	0·32	37·08	10·36	88·07	–1·07
7	22·902	14·952	1·001	39·33	·33	36·86	10·45	88·02	1·07
9	22·915	15·026	0·998	39·09	·33	36·64	10·53	87·98	1·06

Greenwich Noon.		Brightness in Star Magn.	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O.	B.
1897.		m	°	°	°	m	°	°
Feb.	24	−2·05	272·96	310·35	...	36·672	19·8794	−1·0470
	26	−2·05	229·01	251·15	...	36·682	20·0333	1·0548
	28	−2·05	185·06	191·94	·00	36·702	20·1872	1·0625
Mar.	2	−2·04	141·10	132·72	−0·01	36·733	20·3410	1·0702
	4	−2·04	97·14	73·49	·01	36·774	20·4948	1·0779
	6	−2·04	53·16	14·25	·02	36·825	20·6486	−1·0856
	8	−2·03	9·17	315·00	·03	36·887	20·8024	1·0933
	10	−2·03	325·17	255·74	·04	36·958	20·9561	1·1010
	12	−2·02	281·16	196·48	[illegible]	37·039	21·1098	1·1087
	14	−2·02	237·14	137·20	·06	37·130	21·2635	1·1164
	16	−2·01	193·10	77·90	−0·08	37·231	21·4172	−1·1241
	18	−2·01	149·05	18·59	·09	37·341	21·5708	1·1318
	20	−2·00	104·99	319·27	·11	37·459	21·7244	1·1394
	22	−1·99	60·92	259·94	·12	37·587	21·8780	1·1471
	24	−1·98	16·83	200·59	·14	37·723	22·0316	1·1547
	26	−1·97	332·73	141·22	−0·16	37·868	22·1852	−1·1623
	28	−1·96	[illegible]	81·85	·17	38·021	22·3387	1·1699
	30	−1·95	244·47	22·46	·19	38·182	22·4922	1·1775
Apr.	1	−1·[illegible]	200·32	323·05	·21	38·351	22·6457	1·1851
	3	−1·93	156·16	263·62	·23	38·527	22·7992	1·1927
	5	−1·92	111·98	204·18	−0·25	38·710	22·9527	−1·2003
	7	−1·91	67·78	144·73	·27	38·900	23·1061	1·2079
	9	−1·90	23·57	85·26	·28	39·096	23·2595	1·2155
	11	−1·89	339·34	25·77	·30	39·299	23·4129	1·2230
	13	−1·88	295·10	326·27	·32	39·507	23·5663	1·2305
	15	−1·86	250·84	266·75	−0·34	39·721	23·7196	−1·2380
	17	−1·85	206·57	207·22	·35	39·940	23·8729	1·2455
	19	−1·84	162·28	147·67	·37	40·164	24·0262	1·2530
	21	−1·83	117·98	88·11	·38	40·393	24·1795	1·2605
	23	−1·81	73·66	28·53	·40	40·626	24·3327	1·2680
	25	−1·[illegible]	29·33	328·94	−0·41	40·864	24·4859	−1·2755
	27	−1·79	344·98	269·33	·42	41·105	24·6391	1·2830
	29	−1·77	300·62	209·71	·44	41·349	24·7923	1·2905
May	1	−1·76	256·24	150·08	·45	41·597	24·9455	1·2979
	3	−1·75	211·85	90·43	·46	41·847	25·0986	1·3053
	5	−1·73	167·45	30·77	−0·47	42·100	25·2517	−1·3127
	7	−1·72	123·03	331·09	·48	42·355	25·4048	1·3201
	9	−1·71	78·60	271·4	·48	42·612	25·5579	1·3275

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b	d.	w.	B′.
1897.	°	°	°	″	″	″	°	°	°
May 11	22·931	15·111	0·996	38·85	·33	36·42	10·60	87·93	1·06
13	22·949	15·208	0·994	38·62	·33	36·20	10·66	87·89	1·06
15	22·969	15·317	−0·992	38·39	0·33	35·98	10·70	87·85	−1·06
17	22·991	15·437	0·991	38·16	·33	35·76	10·74	87·80	1·06
19	23·015	15·568	0·991	37·93	·33	35·55	10·76	87·76	1·06
21	23·041	15·709	0·991	37·70	·33	35·34	10·77	87·72	1·06
23	23·068	15·860	0·991	37·48	·33	35·13	10·77	87·69	1·06
25	23·097	16·022	−0·992	37·26	0·33	34·92	10·76	87·65	−1·06
27	23·128	16·195	0·993	37·04	·32	34·72	10·74	87·61	1·06
29	23·160	16·378	0·995	36·83	·32	34·52	10·71	87·57	1·06
31	23·194	16·570	0·997	36·62	·32	34·32	10·67	87·53	1·06
June 2	23·230	16·772	0·999	36·41	·31	34·12	10·63	87·49	1·07
4	23·267	16·983	−1·002	36·20	0·31	33·93	10·57	87·46	−1·07
6	23·305	17·204	1·006	36·00	·30	33·74	10·50	87·42	1·07
8	23·344	17·434	1·010	35·81	·30	33·56	10·42	87·38	1·08
10	23·384	17·672	1·014	35·61	·29	33·38	10·33	87·34	1·08
12	23·426	17·918	1·019	35·42	·28	33·20	10·24	87·31	1·09
14	23·469	18·173	−1·024	35·24	0·28	33·03	10·14	87·27	−1·09
16	23·513	18·436	1·030	35·06	·27	32·86	10·03	87·23	1·10
18	23·557	18·707	1·036	34·88	·26	32·69	9·91	87·19	1·11
20	23·601	18·985	1·042	34·70	·25	32·53	9·79	87·15	1·11
22	23·646	19·271	1·049	34·53	·24	32·37	9·65	87·11	1·12
24	23·693	19·564	−1·056	34·37	0·24	32·21	9·51	87·07	−1·13
26	23·740	19·864	1·063	34·21	·23	32·06	9·36	87·03	1·13
28	23·787	20·171	1·071	34·05	·22	31·91	9·21	86·99	1·14
30	23·834	20·485	1·079	33·89	·21	31·77	9·05	86·95	1·15
July 2	23·882	20·806	1·088	33·74	·20	31·63	8·88	86·91	1·16
4	23·930	21·132	−1·097	33·60	0·19	31·49	8·71	86·86	−1·17
6	23·978	21·464	1·106	33·46	·18	31·36	8·53	86·81	1·18
8	24·027	21·802	1·116	33·32	·18	31·23	8·34	86·76	1·19
10	24·075	22·146	1·126	33·19	·17	31·10	8·15	86·71	1·20
12	24·123	22·496	1·136	33·06	·16	30·98	7·95	86·66	1·21
14	24·170	22·850	−1·147	32·93	0·15	30·87	7·75	86·60	−1·22

Greenwich Noon.	Brightness in Star Magn.	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	*A*–O.	*B*.
1897.	m	°	°	°	m	°	°
May 11	–1·69	34·15	211·70	·49	42·871	25·7109	1·3349
13	–1·68	349·70	151·99	·49	43·131	25·8639	1·3423
15	–1·67	305·23	92·26	–0·50	43·392	26·0169	–1·3496
17	–1·65	260·75	32·52	·50	43·654	26·1699	1·3570
19	–1·64	216·26	332·77	·50	43·916	26·3229	1·3644
21	–1·63	171·76	273·01	·50	44·179	26·4758	1·3717
23	–1·61	127·24	213·24	·50	44·442	26·6287	1·3790
25	–1·60	82·72	153·46	–0·50	44·705	26·7816	–1·3863
27	–1·59	38·19	93·67	·50	44·967	26·9345	1·3939
29	–1·58	353·65	33·87	·50	45·229	27·0874	1·4009
31	–1·56	309·10	334·06	·50	45·490	27·2403	1·4082
June 2	–1·55	264·54	274·24	·49	45·749	27·3931	1·4155
4	–1·54	219·97	214·41	–0·49	46·007	27·5459	–1·4227
6	–1·53	175·39	154·57	·48	46·264	27·6987	1·4300
8	–1·51	130·81	94·73	·47	46·519	27·8515	1·4372
10	–1·50	86·22	34·88	·46	46·771	28·0042	1·4444
12	–1·49	41·62	335·02	·46	47·022	28·1570	1·4516
14	–1·48	357·01	275·16	–0·45	47·270	28·3097	–1·4588
16	–1·47	312·40	215·29	·44	47·515	28·4624	1·4660
18	–1·46	267·78	155·41	·43	47·757	28·6151	1·4732
20	–1·45	223·15	95·53	·42	47·997	28·7678	1·4804
22	–1·44	178·52	35·64	·41	48·233	28·9204	1·4876
24	–1·43	133·89	335·75	–0·39	48·467	29·0730	–1·4947
26	–1·42	89·25	275·85	·38	48·696	29·2256	1·5019
28	–1·41	44·60	215·94	·37	48·922	29·3782	1·5090
30	–1·40	359·95	156·03	·36	49·144	29·5308	1·5161
July 2	–1·39	315·30	96·12	·34	49·362	29·6833	1·5232
4	–1·38	270·64	36·21	–0·33	49·576	29·8358	–1·5303
6	–1·37	225·98	336·29	·32	49·786	29·9883	1·5374
8	–1·36	181·32	276·37	·30	49·991	30·1408	1·5445
10	–1·35	136·65	216·44	·29	50·191	30·2933	1·5515
12	–1·34	91·98	156·51	·28	50·387	30·4457	1·5585
14	–1·33	47·31	96·58	–0·26	50·578	30·5981	–1·5655

P denotes the position-angle of *Jupiter's* axis; $L - O + 180°$ the jovicentric longitude of the Earth reckoned in the plane of the planet's equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere or of the descending node of the planet's equator on its orbit; B the jovicentric latitude of the Earth above the equator.

The apparent equatorial and polar diameters of the disc depend on Professor Barnard's measurements adopted in the ephemeris for the preceding apparition, as they are required for the fifth satellite. It would be well if many of the first-rate instruments and micrometers available for the purpose were made to contribute to the investigation of the dimensions of the disc. The formulæ for finding the distances of the tangents to the limbs in right ascension and declination and in other directions, and also the defects of illumination, are published in vol. xl. p. 490 ff, and in vol. xlv. p. 408. To save trouble, the present ephemeris supplies again the values of d and w.

The brightness of *Jupiter*, expressed in star magnitudes, supposes $-2^{m}\cdot233$ to be the brightness at mean opposition according to Professor G. Müller's determination.

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero-meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians, which bisect the illuminated disc. The following is a list of Greenwich mean times, when the adopted zero-meridians in the two systems will pass the middle of the illuminated disc:—

1896.	I. (877°·90) h m	II. (870°·27) h m	1896.	I. (877°·90) h m	II. (870°·27) h m
Oct. 6	20 39·5	19 55·3		22 25·0	24 0·6
7	16 20·7	15 46·8	Oct. 18	18 6·2	19 52·1
8	12 1·8	11 38·3	19	13 47·3	15 43·6
	21 52·4	21 34·1	20	9 28·4	11 35·1
9	17 33·6	17 25·6		19 19·0	21 30·8
10	13 14·7	13 17·1	21	15 0·1	17 22·3
	23 5·3	23 12·8	22	10 41·2	13 13·8
11	18 46·5	19 4·4		20 31·8	23 9·5
12	14 27·6	14 55·9	23	16 12·9	19 1·0
13	0 18·2	0 51·6	24	11 37	♃'s centre 72″·3
	19 59·3	20 43·1			north of ✱ $9^{m}\cdot0$.
14	15 40·5	16 34·6		11 54·1	14 52·5
15	11 21·6	12 26·1		21 44·6	24 48·2
	21 12·2	22 21·9	25	17 25·7	20 39·7
16	16 53·3	18 13·4	26	13 6·8	16 21·2
17	12 34·5	14 4·9	27	18 38·5	22 18·4

1896.		I. (877°·90) h	m	II. (870°·27) h	m
Oct.	28	14	19·6	18	9·8
	29	10	0·7	14	1·3
		19	51·2	23	57·0
	30	15	32·3	19	48·5
	31	11	13·4	15	39·9
Nov.	1	16	45·1	21	27·1
	2	12	26·2	17	18·5
	3	17	57·8	13	10·0
	4	13	38·9	18	57·1
	5	9	20·0	14	48·6
		19	10·5	24	44·3
	6	14	51·6	20	35·7
	7	10	32·6	16	27·1
	8	16	4·2	12	18·6
	9	11	45·3	18	5·7
	10	17	16·9	13	57·1
	11	12	58·0	19	44·2
	12	18	29·5	15	35·6
	13	14	0·6	21	22·7
	14	19	42·2	17	14·2
	15	15	23·2	13	5·6
	16	11	4·2	18	52·7
	17	16	35·8	14	44·1
	18	12	16·8	10	35·5
		22	7·4	20	31·1
	19	17	48·4	16	22·5
	20	13	29·4	12	13·9
		23	20·0	22	9·6
	21	19	1·0	18	1·0
	22	14	42·0	13	52·4
		24	32·5	23	48·1
	23	10	23·0	9	43·8
		20	13·5	19	39·4
	24	15	54·5	15	30·8
	25	11	35·6	11	22·2
		21	26·1	21	17·9
	26	17	7·1	17	9·2
	27	12	48·1	13	0·6

1896.		I. (877°·90) h	m	II. (870°·27) h	m
Nov.	27	22	38·6	22	56·3
	28	18	19·6	18	47·6
	29	14	0·6	14	39·0
		23	51·1	24	34·6
	30	19	32·1	20	26·0
Dec.	1	15	13·0	16	17·4
	2	10	54·0	12	8·7
		20	44·5	22	4·4
	3	16	25·5	17	55·7
	4	12	6·5	13	47·1
		21	57·0	23	42·7
	5	17	38·0	19	34·0
	6	13	18·9	15	25·4
	7	8	59·9	11	16·7
		18	50·4	21	12·3
	8	14	31·3	17	3·7
	9	10	12·3	12	55·0
		20	2·8	22	50·6
	10	15	43·7	18	41·9
	11	11	24·7	14	33·3
		21	15·2	24	28·9
	12	7	5·7	10	24·6
		16	56·1	20	20·2
	13	12	37·1	16	11·5
	14	8	18·0	12	2·8
		18	8·5	21	58·5
	15	13	49·4	17	49·8
	16	9	30·4	13	41·1
		19	20·9	23	36·7
	17	15	1·8	19	28·0
	18	10	42·7	15	19·3
	19	6	23·7	11	10·6
		16	14·1	21	6·2
	20	11	55·0	16	57·5
	21	7	36·0	12	48·8
		17	26·4	22	44·4
	22	13	7·3	8	40·0
		22	57·8	18	35·7

		I. (877°·90) h m	II. (870°·27) h m
1896. Dec.	23	8 48·3	14 26·9
		18 38·7	24 22·6
	24	14 19·6	10 18·2
		24 10·1	20 13·8
	25	10 0·6	16 5·1
	26	15 31·9	11 56·3
	27	11 12·8	17 43·2
	28	16 44·1	13 34·5
	29	12 25·0	9 25·7
		22 15·5	19 41·4
	30	17 56·4	15 12·6
	31	13 37·3	11 3·9
		23 27·7	20 59·5
1897. Jan.	1	9 18·2	6 55·1
		19 8·6	16 50·7
	2	14 49·5	12 42·0
		24 39·9	22 37·6
	3	10 30·4	8 33·2
		20 20·8	18 28·8
	4	6 11·3	14 20·0
		16 1·7	24 15·6
	5	11 42·6	10 11·3
		21 33·0	20 6·9
	6	7 23·4	6 2·5
		17 13·9	15 58·1
	7	12 54·7	11 49·3
		22 45·2	21 44·9
	8	8 35·6	7 40·5
		18 26·0	17 36·1
	9	14 6·9	13 27·4
		23 57·3	23 23·0
	10	9 47·8	9 18·6
		19 38·2	19 14·2
	11	15 19·0	15 5·4
	12	10 59·9	10 56·6
		20 50·3	20 52·2
	13	6 40·8	6 47·8
		16 31·2	16 43·4

		I. (877°·90) h m	II. (870°·27) h m
1897. Jan.	14	12 12·0	12 34·6
		22 2·5	22 30·2
	15	7 52·9	8 25·8
		17 43·3	18 41·4
	16	13 24·2	14 12·6
	17	9 5·0	10 3·8
		18 55·4	19 59·4
	18	14 36·3	15 50·6
	19	10 17·1	11 41·8
		20 7·5	21 37·4
	20	5 57·9	7 33·0
		15 48·4	17 28·6
	21	11 29·2	13 19·8
		21 19·6	23 15·4
	22	7 10·0	9 10·9
		17 0·4	19 6·5
	23	12 41·3	14 57·7
	24	8 22·1	10 48·9
		18 12·5	20 44·5
	25	4 2·9	6 40·1
		13 53·3	16 35·7
	26	9 34·2	12 26·8
		19 24·6	22 22·4
	27	5 15·0	8 18·0
		15 5·4	18 13·6
	28	10 46·2	4 9·2
		20 36·6	14 4·8
	29	6 27·0	9 56·0
		16 17·5	19 51·6
	30	11 58·3	5 47·1
		21 48·7	15 42·7
	31	7 39·1	11 33·9
		17 29·5	21 29·5
Feb.	1	13 10·3	7 25·0
		23 0·7	17 20·6
	2	8 51·1	13 11·8
		18 41·5	23 7·4
	3	4 32·0	9 3·0

1897.		I. (877°·90) h m	II. (870°·27) h m
Feb.	3	14 22·4	18 58·5
	4	10 3·2	4 54·1
		19 53·6	14 49·7
	5	5 44·0	10 40·9
		15 34·4	20 36·5
	6	11 15·2	6 32·0
		21 5·6	16 27·6
	7	6 56·0	12 18·8
		16 46·4	22 14·4
	8	12 27·2	8 10·0
		22 17·7	18 5·5
	9	8 8·1	4 1·1
		17 58·5	13 56·7
	10	3 48·9	9 47·9
		13 39·3	19 43·5
	11	9 20·1	5 39·0
		19 10·5	15 34·6
	12	5 c·9	11 25·8
		14 51·3	21 21·4
	13	10 32·1	7 16·9
		20 22·5	17 12·5
		22 35·5	♃'s centre 30″·8 north of ✱ $8^{m}\cdot8$.
	14	6 12·9	3 8·1
		16 3·3	13 3·7
	15	11 44·1	8 54·8
		21 34·6	18 50·4
	16	7 25·0	4 46·0
		17 15·4	14 41·6
	17	3 5·8	10 32·8
		12 56·2	20 28·4
	18	8 37·0	6 24·0
		18 27·4	16 19·5
	19	4 17·8	2 15·1
		14 8·2	12 10·7
	20	9 49·1	8 1·9
		19 39·5	17 57·4
	21	5 29·9	3 53·0

1897.		I. (877°·90) h m	II. (870°·27) h m
Feb.	21	15 20·3	13 48·6
	22	11 1·1	9 39·8
		20 51·5	19 35·4
	23	6 41·9	5 31·0
		16 32·3	15 26·6
	24	12 13·2	11 17·7
		22 3·5	21 13·3
	25	7 54·0	7 8·9
		17 44·4	17 4·5
	26	3 34·8	3 0·1
		13 15·2	12 55·7
	27	9 6·1	8 46·9
		18 56·5	18 42·5
	28	4 46·9	4 38·1
		14 27·3	14 33·6
Mar.	1	10 18·2	10 24·8
		20 8·6	20 20·4
	2	5 59·0	6 16·0
		15 49·4	16 11·6
	3	11 30·3	12 2·8
		21 20·7	21 58·4
	4	7 11·1	7 54·0
		17 1·6	17 49·6
	5	2 52·0	3 45·2
		12 42·4	13 40·9
	6	8 23·3	9 32·1
		18 13·7	19 27·7
	7	4 4·1	5 23·3
		13 54·6	15 18·9
	8	9 35·4	11 10·1
		19 25·9	21 5·7
	9	5 16·3	7 1·3
		15 6·7	16 56·9
	10	10 47·3	12 48·2
	11	6 28·5	8 39·4
		16 18·9	18 35·0
	12	2 9·4	4 30·6
		11 59·8	14 26·2

1897.	I. (877°·90) h m	II. (870°·27) h m
Mar. 13	7 40·7	10 17·5
	17 31·3	20 13·1
14	3 21·6	6 8·7
	13 12·1	16 4·3
15	8 53·0	11 55·6
16	4 33·9	7 46·9
	14 24·3	17 42·5
17	10 5·2	3 38·1
	19 55·7	13 33·7
18	5 46·1	9 25·0
	15 36·6	19 20·7
19	1 27·1	5 16·3
	11 17·5	15 11·9
20	6 58·4	11 3·2
21	2 39·4	6 54·5
	12 29·8	16 50·1
22	8 10·8	12 41·4
23	3 51·7	8 32·7
	13 42·2	18 28·3
24	9 23·1	4 24·0
	19 13·6	14 19·6
25	5 4·0	10 10·9
	14 54·5	20 6·6
26	10 35·5	6 2·2
	20 25·9	15 57·9
27	6 16·4	11 49·2
28	1 57·4	7 40·5
	11 47·9	17 36·2
29	7 28·8	3 31·8
	17 19·3	13 27·5
30	3 9·8	9 18·8
	13 0·3	19 14·4
31	8 41·3	5 10·0
	18 31·8	15 5·7
Apr. 1	4 22·3	10 57·1
	14 12·7	20 52·8
2	9 53·7	6 48·5
	19 44·2	16 44·2

1897.	I. (877°·90) h m	II. (870°·27) h m
Apr. 3	5 34·7	2 39·8
	15 25·2	12 35·5
4	1 15·7	8 26·9
	11 6·2	18 22·5
5	6 47·2	4 18·2
	16 37·7	14 13·9
6	12 18·8	10 5·3
7	7 59·8	5 56·6
	17 50·3	15 52·3
8	13 31·3	11 43·7
9	9 12·3	7 35·1
	19 2·8	17 30·8
10	4 53·3	3 26·5
	14 43·9	13 22·1
11	10 24·9	9 13·5
	20 15·4	19 9·2
12	6 5·9	5 4·9
	15 56·5	15 0·6
13	11 37·5	10 52·0
14	7 18·6	6 43·5
	17 9·1	16 39·2
15	12 50·1	12 30·6
16	8 31·2	8 22·0
	18 21·7	18 17·7
17	4 12·3	4 13·4
	14 2·8	14 9·1
18	9 43·9	10 0·5
	19 34·4	19 56·3
19	5 24·9	5 52·0
	15 15·5	15 47·7
20	10 56·5	11 39·1
21	6 37·6	7 30·5
	16 28·2	17 26·3
22	2 18·7	3 22·0
	12 9·3	13 17·7
23	7 50·4	9 9·2
	17 40·9	19 4·9
24	3 31·5	5 0·6

1897.		I. (877°·90) h m	II. (870°·27) h m
Apr.	24	13 22·0	14 56·3
	25	9 3·1	10 47·8
	26	4 44·2	6 39·3
		14 34·8	16 35·0
	27	10 15·9	12 26·5
	28	5 57·0	8 17·9
		15 47·6	18 13·7
	29	11 28·7	14 5·1
	30	7 9·8	9 56·6
		17 0·4	19 52·4
May	1	2 50·9	5 48·1
		12 41·5	15 43·9
	2	8 22·6	11 35·4
	3	4 3·8	7 26·9
		13 54·4	17 22·6
	4	9 35·5	13 14·1
	5	5 16·6	9 5·6
		15 7·2	19 1·4
	6	10 48·4	14 52·9
	7	6 29·5	10 44·4
	8	2 10·7	6 35·9
		12 1·3	16 31·7
	9	7 42·4	12 23·2
	10	3 23·6	8 14·7
		13 14·2	18 10·5
	11	8 55·4	4 6·2
		18 45·9	14 2·0
	12	4 36·5	9 53·5
		14 27·1	19 49·3
	13	10 8·3	5 45·1
		19 58·9	15 40·8
	14	15 40·1	11 32·4
	15	1 30·7	7 23·9
		11 21·3	17 19·7
	16	7 2·4	13 11·2
	17	2 43·6	9 2·8
		12 34·2	18 58·5
	18	8 15·4	4 54·3

1897.		I. (877°·90) h m	II. (870°·27) h m
May	18	18 6·0	14 50·1
	19	13 47·2	10 41·7
	20	9 28·4	6 33·3
		19 19·0	16 29·0
	21	15 0·3	12 20·6
	22	10 41·5	8 12·1
	23	6 22·7	4 3·7
		16 23·3	13 59·5
	24	11 54·5	9 51·1
	25	7 35·7	5 42·6
		17 26·3	15 38·4
	26	13 7·5	11 30·0
	27	8 48·8	7 21·6
		18 39·4	17 17·4
	28	14 20·6	13 9·0
	29	10 1·8	9 0·6
	30	15 33·7	14 48·0
	31	11 14·9	10 39·6
June	1	6 56·2	6 31·2
		16 46·8	16 27·0
	2	12 28·1	12 18·6
	3	8 9·3	8 10·2
		17 59·9	18 6·0
	4	3 50·5	4 1·8
		9 5	♃'s centre 38″·6 south of ✱ 8^m·4.
		13 41·2	13 57·6
	5	9 22·4	9 49·2
	6	14 54·3	15 36·6
	7	10 35·5	11 28·2
	8	6 16·8	7 19·8
		16 7·4	17 15·6
	9	11 48·7	13 7·2
	10	7 29·9	8 58·8
	11	13 1·8	14 46·3
	12	8 43·1	10 37·9
	13	4 24·4	6 29·5
		14 15·0	16 25·3

1897.	I. (877°·90) h m	II. (870°·27) h m	1897.	I. (877°·90) h m	II. (870°·27) h m
June 14	9 56·3	12 17·0	June 30	9 51·3	15 34·0
15	5 37·5	8 8·6	July 1	5 32·6	11 25·6
16	11 9·4	13 56·0	2	11 4·5	7 17·3
17	6 50·7	9 47·7	3	6 45·8	13 4·8
18	12 22·6	15 35·1	4	12 17·8	8 56·4
19	8 3·9	11 26·8	5	7 59·1	14 43·9
20	13 35·8	7 18·4	6	13 31·1	10 35·6
21	9 17·1	13 5·9	7	9 12·4	6 27·3
22	4 58·4	8 57·5	8	4 53·7	12 14·8
23	10 30·3	14 45·0	9	10 25·6	8 6·4
24	6 11·6	10 36·6	10	6 6·9	13 53·9
25	11 43 6	6 28·2	11	11 38·9	9 45·6
26	7 24·8	12 15·7	12	7 20·2	15 33·1
27	12 56·8	8 7·4	13	12 52·1	11 24·7
28	8 38·1	13 54·9	14	8 33·5	7 16·4
29	4 19·4	9 46·5			

The intervals between successive passages of the zero-meridian vary in System I. between $9^h\ 50^m{\cdot}40$ and $50^m{\cdot}66$, and in II. between $9^h\ 55^m{\cdot}58$ and $55^m{\cdot}84$. The differences of successive values of the longitude of ♃'s Central Meridian for the two days interval vary in System I. between $1755^\circ{\cdot}33$ and $1756^\circ{\cdot}09$, and in II. between $1740^\circ{\cdot}07$ and $1740^\circ{\cdot}83$.

Though System I. has, for some years past, ceased to represent the motion of any special spot, I continue to give it, so that it may be ready for being of use in the reduction of the observations of any equatorial spots. The rate of motion of the great reddish spot has been during eleven years so near the adopted $870^\circ{\cdot}27$ of System II., that the longitude of the middle of the spot has remained within 10° of the adopted zero-meridian. The only observed passages across the middle meridian of the disc made during the planet's last apparition, which have yet reached me, are the following four, kindly communicated by Mr. Denning:

			h m	°				h m	°
1895	Aug.	24	16 24	$\omega=5{\cdot}7$	1896	Feb.	10	6 49	$\omega=8{\cdot}3$
	Sept.	29	16 11	3·3			22	6 43	8·7

to which I can now add the first of the present apparition, which Mr. Denning has been on the alert to secure, 1896 September 27 $17^h\ 43^m\ \omega=8^\circ{\cdot}9$, so that the middle of the spot follows the zero-meridian about a quarter of an hour.

The observed passages of the second of the two dark spots observable during last season in *Jupiter's* northern hemisphere indicate that its daily rate of rotation has been very nearly $0^{\circ}\cdot20$ greater than that of the zero-meridian II., and that its longitude has been $270^{\circ}\cdot50 - 0^{\circ}\cdot20$ (t − 1896 January 21·0). The residual differences between the longitudes ω corresponding to the observed times and the longitudes given by this formula are found in the following list, which contains all the observed passages which hitherto have come to my knowledge :

	G.M.T.	ω	O−C.	Observer.	References.
1895.	h m	°	°		
Sept. 26	16 45	293·3	−0·1	Denning	Observatory, p. 327
Oct. 27	17 15	288·3	+0·7	MacEwen*	
Nov. 15	17 48	283·7	0·0	Brenner	Bull. Soc. Ast. Fr., p. 31
23	14 20	280·6	−1·6	Lunt*	
1896.					
Jan. 15	12 48	275·4	+3·8	Lunt*	
25	10 55·5	271·3	+1·7	Brenner	Journ. B. A. A., p. 214
28	8 21	269·1	+0·1	Gledhill	Monthly Not., p. 483
	8 22	269·7	+0·7	MacEwen*	
30	9 58	268·5	−0·1	Gledhill	
Feb. 2	7 22	265·4	−2·7	MacEwen*	
4	9 2	266·6	−1·1	Denning	
6	10 41	267·1	−0·1	Gledhill	
	10 46	270·2	+2·9	Brenner	
9	8 6	264·5	−2·1	Gledhill	
	8 9·91	266·90	+0·27	Martin†	
	8 14	269·4	+2·7	Brenner	
10	13 51·25	263·56	−2·02	Martin	
11	9 40	262·1	−4·2	Gledhill	
	9 50·56	268·43	+2·21	Martin	
	9 51·5	269·0	+2·8	Brenner	
13	11 23·48	265·30	−0·50	Martin	
14	7 16	266·1	+0·4	Gledhill	
16	9 5	267·0	+1·7	Antoniadi	Bull. Soc. Ast. Fr., p. 101
18	0 35·4	265·3	+0·4	Morfield	Journ. B. A. A., p. 388
20	12 7·24	264·07	−0·33	Rambaut†	
21	7 57	263·1	−1·1	MacEwen*	
	7 57·76	263·47	−0·76	Rambaut	
	7 59	264·3	+0·1	Denning	

* Communicated by Mr. Waugh in advance of the Fifth Report of the *Jupiter* Section of the British Astronomical Association.

† "Scientific Proceedings of the Royal Dublin Society," vol. viii. p. 397.

1896.		G.M.T. h m	ω °	O–C. °	Observer.	References.
Feb.	23	9 35	263·0	−0·8	Gledhill	
		9 37·25	264·33	+0·51	Rambaut	
	24	5 30	265·2	+1·6	Gledhill	
	26	7 5·96	263·82	+0·58	Rambaut	
		7 6	263·8	+0·6	Gledhill	
Mar.	1	10 15	259·2	−3·2	,,	
		10 20·30	262·41	0·00	Rambaut	
	4	7 48	261·2	−0·6	Gledhill	
	5	23 38·4	265·8	+4·3	Merfield	
	6	9 25	260·3	−1·1	Gledhill	
	8	1 15·4	265·0	+3·9	Merfield	
	8	11 5	261·3	+0·3	Gledhill	
	9	6 55	260·4	−0·4	,,	
		6 55·98	261·02	+0·18	Rambaut	
		6 58	262·2	+1·4	MacEwen	
	11	8 33	260·1	−0·3	Brenner	
	15	21 50·4	263·0	+3·4	Merfield	
	16	7 39·61	259·03	−0·41	Rambaut	
		7 43	261·1	+1·6	Gledhill	
		7 44	261·7	+2·2	Brenner	Journ. B. A. A., p. 272
	18	9 18·5	259·2	+0·2	,,	
		9 20	260·1	+1·1	Gledhill	
	22	12 36·78	259·87	+1·68	Hartwig	Astr. Nachr. 140, p. 167
	22	22 32·4	259·8	+1·7	Merfield	
	23	8 22	256·1	−1·9	Gledhill	
		8 24	257·3	−0·7	Brenner	
		8 25·4	258·1	+0·1	Lamp	Astr. Nachr. 140, p. 169
		8 27·6	259·5	+1·5	Villiger	,, ,, p. 320
		8 27·70	259·54	+1·51	Hartwig	
	25	9 57	253·9	−3·7	Gledhill	
	26	5 57	259·1	+1·6	Brenner	
	28	7 30	255·6	−1·4	Gledhill	
	30	9 9	255·8	−0·9	,,	
Apr.	4	8 19	256·4	+0·7	Brenner	
	9	7 23	253·2	−1·4	Gledhill	
	11	8 58	250·9	−3·3	,,	
	16	8 6	250·1	−3·1	,,	
	18	9 45·5	250·5	−2·3	,,	
	20	11 29	253·2	+0·8	,,	

1896.	G.M.T. h m	ω °	O−C. °	Observer.	References.
Apr. 23	8 54	249·9	−1·9	Gledhill	
28	8 3	249·6	−1·2	„	
	8 11	254·4	+3·6	Brenner	Journ. B. A. A., p. 424
30	9 43	250·2	−0·2	Gledhill	
May 5	8 50·5	248·9	−0·5	„	
10	8 0	248·7	+0·3	„	
June 8	6 54	240·4	−2·3	Brenner	

In case this garnet spot has not meanwhile vanished and keeps moving at the daily rate of rotation $870°·47$ (corresponding to the period $9^h\ 55^m\ 32^s·42$), it may be looked for

on Oct. 27 in long. $214°·5$, or $4^h\ 1^m$ preceding the zero-meridian II.
on Dec. 26 „ $202·5$ „ 4 21 „ „ „ „

If, on *Jupiter's* spheroidal surface, ω is the (jovicentrically western) longitude of a spot or marking in the adopted system of longitudes, ω_0 that of the central meridian, and β' the latitude of the spot, the apparent co-ordinates x and y of the spot, referred to the semiaxes a and b, will be

$$x = a \sin(\omega - \omega_0) \cos \beta'$$
$$y = b \sin(\beta' - B') + x \tan^2 \tfrac{1}{2} (\omega - \omega_0) \sin B$$

where $\tan B' = \tan B \sec \epsilon_0$ and $\tan \beta' = \tan \beta \sec \epsilon_0$, if β is the jovicentric latitude, which is, however, not wanted. Near the central meridian the second term of y is insignificant, so that β' is found by

$$\sin(\beta' - B') = \frac{y}{b},$$

and ω by

$$\sin(\omega - \omega_0) = \frac{x}{a} \sec \beta',$$

the defect of illumination being duly taken into account in measuring.

The star $9^m·0$, near which *Jupiter* passes on October 24, is W.B. $10^h·445$. On February 13 the star $8^m·8$, BD + $10°·2181$ = W.B. $10^h·580$, will be in conjunction with the

	h m	″	
preceding border of the disc at ...	21 24	31·7	south
Centre „ „ ...	22 35·5	30·8	„
following limb „ ...	23 47	29·8	„

so that, if the unchecked place from W.B. can be depended on, the star will come within 10″ of the southern limb of the disc. The star of June 4 is Ll. 20183 and also star *f* on p. 280 of *Astr. Nachr.* vol. liii. Its conjunction with the following border occurs at $7^h\ 59^m$, 39″·2 north, and with the preceding limb at $9^h\ 5^m$, 38″·6 north.

Data for Computing the Positions of the Satellites of Jupiter, 1896–97. By A. Marth.

The following data for computing the places of the satellites for the approaching apparition of *Jupiter* are a continuation of those for the preceding apparitions published in vols. li.–lv. of the *Monthly Notices*. They furnish, at intervals of ten days, the mean longitudes l of the satellites and the arguments of their inequalities. The motions of the longitudes and arguments during the intervals, and the inequalities corresponding to the arguments, are to be found on pp. 524–539 of vol. li.

The inclinations γ and the longitudes of the nodes Γ of the planes of the orbits referred to the plane of *Jupiter's* equator are the following:—

		Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
		γ_1	$\mathrm{O}-\Gamma_1$	γ_2	$\mathrm{O}-\Gamma_2$	γ_3	$\mathrm{O}-\Gamma_3$	γ_4	$\mathrm{O}-\Gamma_4$
1896.		°	°	°	°	°	°	°	°
Sept.	17	0·0097	187·0	0·4807	180·63	0·1265	131·80	0·3378	29·44
Oct.	17	96	188·2	·4804	181·60	·1265	131·95	·3379	29·49
Nov.	16	95	189·5	·4802	182·57	·1265	132·09	·3380	29·54
Dec.	16	95	190·8	·4799	183·54	·1265	132·24	·3381	29·58
1897.									
Jan.	15	94	192·1	·4796	184·52	·1265	132·38	·3383	29·62
Feb.	14	0·0093	193·4	0·4794	185·49	0·1265	132·52	0·3385	29·66
Mar.	16	92	194·6	·4791	186·47	·1265	132·66	·3387	29·69
Apr.	15	92	195·9	·4788	187·44	·1264	132·81	·3388	29·72
May	15	91	197·1	·4785	188·42	·1264	132·95	·3390	29·74
June	14	90	198·4	·4782	189·40	·1263	133·10	·3392	29·76
July	14	0·0089	199·6	0·4780	190·38	0·1263	133·25	0·3394	29·77

The rectangular co-ordinates of the satellites referred to the axes of the disc of *Jupiter* are found by means of the formulæ (*v.* vol. li. p. 506):

$$\Delta' = \Delta + a\rho \cos B \cos (v - L)$$

$$x = \frac{a''}{\Delta'} \cdot \rho \sin (v - L)$$

$$y = \frac{a''}{\Delta'} \cdot \rho \left(\cos (v - L) \sin B + \sin \gamma \cos B \cdot \sin (v - \Gamma)\right).$$

The values of the distance Δ of *Jupiter* from the Earth and of L and B are to be interpolated for the times t, for which the positions are required, but those of l and of the arguments on which the true longitudes v and the rad. vect. ρ depend, for the times $t - \tau$, if τ is the light-time given in the ephemeris for physical observations. There are also found the jovicentric apparent longitudes $\Lambda - O + 180°$, and latitudes B of the Sun referred to the planet's equator.

First Satellite.

Greenwich Noon.		Longitude. l_1-O	S_1	Arguments. α_1	β_1	γ_1	δ_1	ϵ_1
1896.		°	°					
Oct.	7	10·0399	−·0016	·8232	·956	·614	·421	·209
	17	244·9295	17	·4962	·374	·262	·073	·234
	27	119·8190	17	·1692	·792	·911	·725	·259
Nov.	6	354·7086	18	·8422	·211	·559	·377	·283
	16	229·5982	−·0019	·5152	·629	·207	·030	·308
	26	104·4877	19	·1882	·047	·856	·682	·333
Dec.	6	339·3773	20	·8612	·465	·504	·334	·357
	16	214·2668	21	·5342	·884	·152	·986	·382
	26	89·1564	22	·2073	·302	·801	·639	·407
1897. Jan.	5	324·0460	22	·8803	·720	·449	·291	·431
	15	198·9355	−·0023	·5533	·138	·097	·943	·456
	25	73·8251	24	·2263	·557	·745	·596	·481
Feb.	4	308·7146	25	·8993	·975	·393	·248	·505
	14	183·6042	25	·5723	·393	·042	·900	·530
	24	58·4938	26	·2453	·811	·690	·552	·555
Mar.	6	293·3833	27	·9183	·230	·339	·205	·580
	16	168·2729	−·0028	·5914	·648	·987	·857	·604
	26	43·1624	28	·2644	·066	·635	·509	·629
Apr.	5	278·0520	29	·9374	·484	·284	·161	·654
	15	152·9416	30	·6104	·903	·932	·814	·678
	25	27·8311	31	·2834	·321	·580	·466	·703
May	5	262·7207	31	·9564	·739	·229	·118	·728
	15	137·6102	−·0032	·6294	·157	·877	·771	·752
	25	12·4998	33	·3024	·576	·525	·423	·777
June	4	247·3894	34	·9755	·994	·174	·075	·802
	14	122·2789	34	·6485	·412	·822	·727	·826
	24	357·1685	35	·3215	·830	·470	·380	·851
July	4	232·0580	36	·9945	·249	·119	·032	·876
	14	106·9476	−·0037	·6675	·667	·767	·684	·900

Greenwich Noon.	*First Satellite.* Arguments. ζ_1	η_1	θ_1	*Second Satellite.* Longitude. l_2-O	S_2	Arguments. α_2	β_2
1896.				°	°		
Oct. 7	·643	·903	·713	221·8720	−·0078	·91158	·956
17	·665	·923	·734	155·6192	77	·74808	·374
27	·687	·944	·755	89·3665	77	·58459	·792
Nov. 6	·709	·965	·775	323·1138	76	·42110	·211
16	·730	·986	·795	316·8610	−·0075	·25760	·629
26	·752	·006	·816	250·6083	75	·09411	·047
Dec. 6	·774	·027	·837	184·3555	74	·93062	·465
16	·796	·048	·857	118·1028	73	·76712	·884
26	·817	·069	·878	51·8500	72	·60363	·302
1897. Jan. 5	·839	·089	·898	345·5973	72	·44014	·720
15	·861	·110	·919	279·3446	−·0071	·27664	·138
25	·883	·131	·940	213·0918	70	·11315	·557
Feb. 4	·904	·152	·960	146·8391	69	·94965	·975
14	·926	·172	·981	80·5863	68	·78616	·393
24	·948	·193	·001	14·3336	67	·62267	·811
Mar. 6	·970	·214	·022	308·0808	67	·45917	·230
16	·991	·234	·043	241·8281	−·0066	·29568	·648
26	·013	·255	·063	175·5753	65	·13219	·066
Apr. 5	·035	·276	·084	109·3226	64	·96869	·484
15	·057	·297	·104	43·0699	63	·80520	·903
25	·078	·317	·125	336·8171	62	·64171	·321
May 5	·100	·338	·146	270·5644	61	·47821	·739
15	·122	·359	·166	204·3116	−·0060	·31472	·157
25	·144	·380	·187	138·0589	59	·15122	·576
June 4	·165	·400	·207	71·8061	58	·98773	·994
14	·187	·421	·228	5·5534	57	·82424	·412
24	·209	·442	·248	299·3006	56	·66074	·830
July 4	·231	·463	·269	233·0479	55	·49725	·249
14	·252	·483	·290	166·7952	−·0054	·33376	·667

Second Satellite.

Greenwich Noon.	Arguments.								
	γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2
1896.									
Oct. 7	·268	·009	·199	·643	·403	·213	·709	·814	.625
17	·083	·825	·015	·665	·423	·234	·734	·671	·482
27	·898	·640	·830	·687	·444	·255	·759	·529	·339
Nov. 6	·712	·456	·646	·709	·465	·275	·783	·386	·196
16	·527	·272	·462	·730	·486	·295	·808	·243	·053
26	·342	·088	·278	·752	·506	·316	·833	·100	·910
Dec. 6	·157	·904	.094	·774	·527	·337	·857	·958	·767
16	·971	·719	·910	·796	·548	·357	·882	·815	·624
26	·786	·535	·926	·817	·569	·378	·907	·672	·481
1897.									
Jan. 5	·601	·351	·942	·839	·589	·398	·931	·529	·338
15	·416	·167	·358	·861	·610	·419	·956	·387	·196
25	·230	·982	·174	·883	·631	·440	·981	·244	·053
Feb. 4	·045	·798	·990	·904	·652	·460	·005	·101	·910
14	·860	·614	·805	·926	·672	·481	·030	·958	·767
24	·675	·430	·621	·948	·693	·501	·055	·816	·624
Mar. 6	·489	·245	·437	·970	·714	·522	·080	·673	·481
16	·304	·061	·253	·991	·734	·543	·104	·530	·338
26	·119	·877	·069	·013	·755	·563	·129	·387	·195
Apr. 5	·934	·693	·885	·035	·776	·584	·154	·245	·052
15	·748	·508	·701	·057	·797	·604	·178	·102	·910
25	·563	·324	·517	·078	·817	·625	·203	·959	·767
May 5	·378	·140	·333	·100	·838	·646	·228	·816	·624
15	·193	·956	·149	·122	·859	·666	·252	·674	·481
25	·008	·772	·965	·144	·880	·687	·277	·531	·338
June 4	·822	·587	·780	·165	·900	·707	·302	·389	·195
14	·637	·403	·596	·187	·921	·728	·326	·245	·052
24	·452	·219	·412	·209	·942	·748	·351	·103	·909
July 4	·267	·035	·228	·231	·963	·769	·376	·960	·766
14	·081	·850	044	·252	·983	·790	·400	·817	·623

Third Satellite.

Greenwich Noon.	Longitude. $l_3 - O$	S_3	Arguments. α_3	β_3	γ_3	δ_3	ϵ_3
1896.	°	°					
Oct. 7	57·7880	−·0091	·5532	·7428	·9558	·091	·858
17	200·9641	90	·9507	·1405	·3740	·890	·297
27	344·1402	89	·3482	·5381	·7923	·688	·736
Nov. 6	127·3163	88	·7457	·9358	·2105	·486	·175
16	270·4924	−·0087	·1432	·3334	·6288	·285	·614
26	53·6685	85	·5407	·7311	·0471	·083	·053
Dec. 6	196·8447	84	·9382	·1287	·4653	·882	·492
16	340·0208	83	·3358	·5264	·8836	·680	·931
26	123·1969	82	·7333	·9243	·3018	·479	·370
1897.							
Jan. 5	266·3730	80	·1308	·3217	·7201	·277	·809
15	49·5491	−·0079	·5283	·7194	·1383	·076	·248
25	192·7252	78	·9258	·1170	·5565	·875	·687
Feb. 4	335·9013	76	·3233	·5147	·9748	·673	·126
14	119·0774	75	·7208	·9123	·3931	·472	·565
24	262·2535	74	·1183	·3100	·8113	·270	·004
Mar. 6	45·4296	72	·5158	·7077	·2296	·069	·443
16	188·6057	−·0071	·9134	·1053	·6478	·867	·882
26	331·7818	69	·3109	·5030	·0661	·666	·321
Apr. 5	114·9579	68	·7084	·9006	·4843	·464	·760
15	258·1340	66	·1059	·2983	·9026	·263	·199
25	41·3101	65	·5034	·6959	·3209	·061	·638
May 5	184·4862	64	·9009	·0936	·7391	·860	·077
15	327·6623	−·0062	·2984	·4913	·1574	·658	·516
25	110·8384	60	·6959	·8889	·5756	·457	·955
June 4	254·0145	59	·0935	·2866	·9939	·255	·394
14	37·1906	57	·4910	·6842	·4121	·054	·833
24	180·3667	55	·8885	·0819	·8304	·852	·272
July 4	323·5428	54	·2860	·4795	·2486	·651	·711
14	106·7189	−·0053	·6835	·8772	·6669	·449	·150

Greenwich Noon. 1896.		Third Satellite. Arguments. ζ_3	η_3	θ_3	ι_3	Fourth Satellite. Longitude. l_4-O °	S_4 °	Arg. a_4
Oct.	7	·643	·903	·713	·312	205·0832	−·0295	·15196
	17	·665	·923	·734	·709	60·7939	·0292	·75110
	27	·687	·944	·755	·105	276·5047	·0289	·35025
Nov.	6	·709	·965	·775	·502	132·2154	·0286	·94939
	16	·730	·986	·795	·898	347·9261	−·0283	·54853
	26	·752	·006	·816	·295	203·6369	·0280	·14767
Dec.	6	·774	·027	·837	·691	59·3476	·0277	·74681
	16	·796	·048	·857	·088	275·0584	·0274	·34596
	26	·817	·069	·878	·484	130·7691	·0271	·94510
1897. Jan.	5	·839	·089	·898	·881	346·4798	·0267	·54424
	15	·861	·110	·919	·277	202·1906	−·0264	·14338
	25	·883	·131	·940	·674	57·9013	·0261	·74252
Feb.	4	·904	·152	·960	·070	273·6121	·0257	·34166
	14	·926	·172	·981	·467	129·3228	·0254	·94081
	24	·948	·193	·001	·863	345·0335	·0250	·53995
Mar.	6	·970	·214	·022	·260	200·7443	·0247	·13909
	16	·991	·234	·043	·656	56·4550	−·0243	·73823
	26	·013	·255	·063	·053	272·1658	·0240	·33737
Apr.	5	·035	·276	·084	·449	127·8765	·0236	·93652
	15	·057	·297	·104	·846	343·5872	·0232	·53566
	25	·078	·317	·125	·242	199·2980	·0229	·13480
May	5	·100	·338	·146	·639	55·0087	·0225	·73394
	15	·122	·359	·166	·035	270·7195	−·0221	·33308
	25	·144	·380	·187	·432	126·4302	·0217	·93223
June	4	·165	·400	·207	·828	342·1409	·0213	·53137
	14	·187	·421	·228	·225	197·8517	·0210	·13051
	24	·209	·442	·248	·621	53·5624	·0206	·72965
July	4	·231	·463	·269	·018	269·2732	·0202	·32879
	14	·252	·483	·290	·414	124·9839	−·0198	·92794

Fourth Satellite.

Greenwich Noon. 1896.		Arguments.					
	β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	θ_4
Oct. 7	·091	·462	·961	·113	·439	·047	·129
17	·890	·061	·555	·306	·638	·263	·328
27	·688	·660	·150	·500	·838	·480	·528
Nov. 6	·486	·259	·745	·694	·037	·697	·727
16	·285	·858	·339	·888	·236	·914	·927
26	·083	·457	·934	·082	·436	·130	·126
Dec. 6	·882	·056	·528	·275	·635	·347	·326
16	·680	·655	·123	·469	·835	·564	·525
26	·479	·254	·718	·663	·034	·781	·725
1897. Jan. 5	·277	·853	·312	·857	·233	·998	·924
15	·076	·452	·907	·050	·433	·214	·124
25	·875	·051	·502	·244	·632	·431	·323
Feb. 4	·673	·650	·096	·438	·831	·648	·523
14	·472	·249	·691	·632	·031	·865	·722
24	·270	·848	·286	·826	·230	·081	·922
Mar. 6	·069	·447	·880	·019	·429	·298	·121
16	·867	·046	·475	·213	·629	·515	·321
26	·666	·645	·069	·407	·828	·732	·520
Apr. 5	·464	·244	·664	·601	·028	·948	·720
15	·263	·843	·259	·794	·227	·165	·919
25	·061	·442	·853	·988	·426	·382	·119
May 5	·860	·041	·448	·182	·626	·599	·318
15	·658	·640	·043	·376	·825	·816	·518
25	·457	·239	·637	·569	·024	·032	·717
June 4	·255	·838	·234	·763	·224	·249	·917
14	·054	·437	·827	·957	·423	·466	·116
24	·852	·036	·421	·151	·623	·683	·316
July 4	·651	·635	·016	·345	·822	·899	·516
14	·449	·234	·610	·538	·021	·116	·715

As no measurements of the fifth satellite made during the last season have yet come to my knowledge, I must content myself with going on with the adopted daily rate of motion 722°·633, deduced from the measures of 1892 and 1893, so that its uncertainty will now appear trebled.

Ephemeris of the Fifth Satellite of Jupiter, 1896–97.

Greenwich Noon. 1896.		P+90°.	a_s	b_s	l_s−L.	Greenwich Times of greatest Elongations.	
		°	"	"	°	h m	h m
Nov.	16	114·11	45·34	−0·80	106·53	17 23 W.	23 22 E.
	18	114·14	45·60	·82	111·70	17 13	23 12
	20	114·17	45·86	·83	116·89	17 3	23 1
	22	114·20	46·12	·85	122·08	16 52	22 51
	24	114·22	46·39	·87	127·29	16 42	22 40
	26	114·25	46·66	−0·89	132·51	16 31 W.	22 30 E.
	28	114·27	46·94	·90	137·74	16 21	22 20
	30	114·29	47·22	·92	142·98	16 11	22 9
Dec.	2	114·31	47·51	·94	148·23	16 0	21 59
	4	114·33	47·80	·96	153·49	15 50	21 48
	6	114·34	48·09	−0·97	158·76	15 39 W.	21 38 E.
	8	114·36	48·38	0·99	164·05	15 28	21 27
	10	114·37	48·67	1·01	169·34	15 18	21 17
	12	114·38	48·97	1·02	174·65	15 7	21 6
	14	114·39	49·27	1·04	179·97	14 57	20 55
	16	114·40	49·57	−1·05	185·30	14 46 W.	20 45 E.
	18	114·41	49·87	1·07	190·65	14 35	20 34
	20	114·41	50·18	1·09	196·00	14 25	20 23
	22	114·42	50·48	1·10	201·37	14 14	20 13
	24	114·42	50·78	1·12	206·74	14 3	20 2
	26	114·42	51·08	−1·13	212·13	13 53 W.	19 51 E.
	28	114·42	51·38	1·15	217·53	13 42	19 41
	30	114·41	51·68	1·16	222·94	13 31	19 30
1897.							
Jan.	1	114·41	51·97	1·17	228·36	13 20	19 19
	3	114·40	52·26	1·19	233·79	13 9	19 8
	5	114·40	52·55	−1·20	239·23	12 59 W.	18 57 E.
	7	114·39	52·84	1·21	244·68	12 48	18 46
	9	114·38	53·12	1·22	250·14	12 37	18 35
	11	114·37	53·39	1·23	255·61	12 26	18 25
Jan.	13	114·35	53·65	1·24	261·09	12 15	18 14
	15	114·34	53·91	−1·25	266·58	12 4 W.	18 3 E.

Greenwich Noon. 1897.		$P+90°$.	a_s	b_s	l_s-L.	Greenwich Times of greatest Elongations.	
		°	″	″	°	h m	h m
Jan.	17	114·32	54·16	1·26	272·07	11 53	17 52
	19	114·30	54·41	1·27	277·57	11 42	17 41
	21	114·28	54·64	1·28	283·08	11 31	17 30
	23	114·26	54·87	1·28	288·60	11 20	17 19
	25	114·24	55·08	−1·29	294·12	11 9 W.	17 8 E.
	27	114·21	55·29	1·29	299·65	10 58	16 57
	29	114·18	55·48	1·30	305·18	10 47	16 46
	31	114·16	55·66	1·30	310·71	10 36	16 35
Feb.	2	114·13	55·83	1·30	316·25	10 25	16 24
	4	114·10	55·98	1·30	321·80	10 14 W.	16 13 E.
		114·07	56·12	−1·30	327·34	10 3	16 2
	8	114·03	56·25	1·30	332·89	9 52	15 51
	10	114·00	56·36	1·30	338·43	9 41	15 40
	12	113·96	56·45	1·30	343·98	9 30	15 28
	14	113·93	56·53	−1·30	349·53	9 19 W.	15 17 E.
	16	113·89	56·60	1·29	355·07	9 8	15 6
	18	113·85	56·65	1·29	0·61	8 57	14 55
	20	113·81	56·68	1·28	6·15	8 46	14 44
	22	113·77	56·70	1·28	11·68	8 35	14 33
	24	113·73	56·70	−1·27	17·21	8 24 W.	14 22 E.
	26	113·69	56·68	1·26	22·73	8 13	14 11
	28	113·65	56·65	1·25	28·25	8 2	14 0
Mar.	2	113·61	56·60	1·24	33·76	7 51	13 49
	4	113·56	56·54	1·23	39·26	7 40	13 38
	6	113·52	56·46	−1·22	44·75	7 29 W.	13 27 E.
	8	113·48	56·37	1·21	50·24	7 18	13 16
	10	113·44	56·26	1·20	55·72	7 7	13 6
	12	113·40	56·14	1·19	61·18	6 56	12 55
	14	113·36	56·00	1·18	66·63	6 45 W.	12 44 E.
	16	113·32	55·85	−1·16	72·08	12 33 E.	18 32 W.
	18	113·28	55·69	1·15	77·51	12 22	18 21
	20	113·24	55·56	1·14	82·92	12 11	18 10
	22	113·21	55·32	1·13	88·33	12 1	17 59
	24	113·17	55·12	1·11	93·72	11 50	17 49
	26	113·14	54·91	−1·10	99·10	11 39 E.	17 38 W.
	28	113·11	54·69	1·08	104·46	11 29	17 27
	30	113·08	54·46	1·07	109·81	11 18	17 17
Apr.	1	113·05	54·22	1·06	115·15	11 7	17 6

Greenwich Noon. 1897.	P+90°.	a_5	b_5	l_5-L.	Greenwich Times of greatest Elongations.	
	°	"	"	°	h m	h m
Apr. 3	113·02	53·97	1·04	120·47	10 57	16 55
5	113·00	53·71	−1·03	125·77	10 46 E.	16 45 W.
7	112·97	53·45	1·02	131·06	10 36	16 34
9	112·95	53·18	1·00	136·34	10 25	16 24
11	112·94	52·91	0·99	141·60	10 15	16 13
13	112·92	52·63	0·98	146·84	10 4	16 3
15	112·90	52·35	−0·97	152·08	9 54 E.	15 52 W.
17	112·89	52·06	·96	157·29	9 43	15 42
19	112·88	51·77	·94	162·49	9 33	15 32
21	112·88	51·48	·93	167·68	9 23	15 21
23	112·87	51·18	·92	172·85	9 12	15 11
25	112·87	50·88	−0·91	178·01	9 2 E.	15 1 W.
27	112·87	50·59	·90	183·16	8 52	14 51
29	112·87	50·29	·89	188·29	8 42	14 40
May 1	112·88	49·99	·88	193·40	8 31	14 30
3	112·88	49·69	·87	198·50	8 21	14 20
5	112·89	49·39	−0·87	203·59	8 11 E.	14 10 W.
7	112·90	49·09	·86	208·67	8 1	14 0
9	112·91	48·79	85	213·73	7 51	13 50
11	112·93	48·50	·84	218 78	7 41	13 40
13	112·95	48·21	·84	223·82	7 31	13 30
15	112·97	47·92	−0·83	228·85	7 21 E.	13 20 W.

The differences between successive values of l_5-L for the interval of two days vary between 1445°·03 and 1445°·55. The values are to be interpolated for the times of the observations, when the corresponding computed co-ordinates will be:

$$x_5 = a_5 \sin (l_5 - \mathrm{L}) \text{ in pos. angle } \mathrm{P} \pm 90^\circ$$
$$y_5 = b_5 \cos (l_5 = \mathrm{L}) \quad ,, \quad ,, \quad \mathrm{P}.$$

It is most desirable that the x measurements should be made before and after the greatest elongations as far away as feasible.

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

INDEX.

LIST OF PRESENTS

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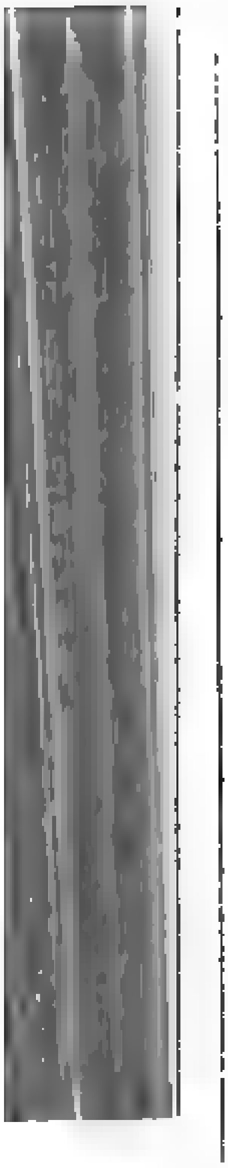

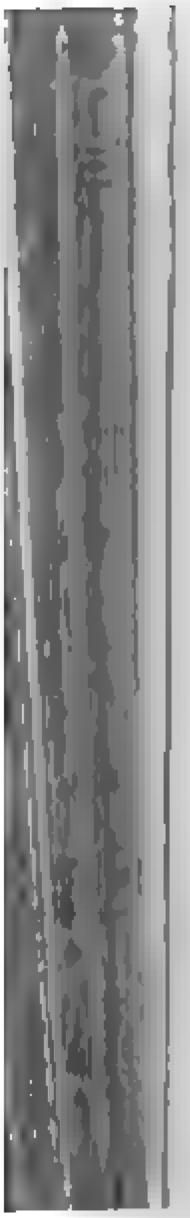

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